THE AUGUST SCIENTIFIC MONTHLY

EDITED BY J. McKEEN CATTELL

THE SCIENCE PRESS
LANCASTER, PA.—GRAND CENTRAL TERMINAL, N. Y. CITY—GARRISON, N. Y.

Yearly Subscription $5.00 Single Copies 50 cents

NEW BOOKS OF SCIENTIFIC INTEREST

Linear Transformations in Hilbert Space. M. H. STONE. viii + 622 pp. $6.50. American Mathematical Society.

One of the American Mathematical Society's Colloquium publications. A volume for both the student and the investigator, including the author's own independent contribution to the subject and also the existing material bearing on linear transformations in Hilbert space and their applications to analysis.

The Mechanics of Deformable Bodies. Vol. II. of "Introduction to Theoretical Physics." MAX PLANCK. Translated by Henry L. Brose. ii + 234 pp. Illustrated. $2.50. Macmillan.

The discussion in this book is divided into three parts, the first dealing with general laws of motion, the others with applications to important kinds of motion. It is an expansion of the first volume on general mechanics, the two together being intended to serve as bases for more detailed work.

Theory of Electricity and Magnetism. Vol. III. of "Introduction to Theoretical Physics." MAX PLANCK. Translated by Henry L. Brose. viii + 247 pp. Illustrated. $2.50. Macmillan.

Professor Planck considers the electrical and the mechanical as the two fundamental types of physical phenomena, and, in order to avoid disintegrating the two, develops his electrical theory in so far as possible in harmony with the mechanical principles of conservation of energy and contiguous action.

The Development of Physical Thought. LEONARD B. LOEB and ARTHUR S. ADAMS. xiv + 648 pp. Illustrated. $3.75. John Wiley.

This text represents an attempt to solve by philosophical and historical treatment the problem of presenting to beginning students without special mathematical training a general knowledge of other than purely qualitative physics.

Introductory College Chemistry. HORACE G. DEMING. xii + 590 pp. Illustrated. $3.00. John Wiley.

This text-book, intended for the first year of college chemistry, stresses general principles, practical applications and historical material in preference to the specific information needed by the professional chemist.

Quantitative Chemical Analysis. GEORGE MCPHAIL SMITH. Third edition. xii + 199 pp. Illustrated. $2.25. Macmillan.

Intended to serve as a second-year college text, the book includes, besides usual sections on gravimetric and volumetric analysis, sections on general information and theory, questions and problems growing out of the lecture and laboratory work.

Earth Oil. GUSTAV EGLOFF. xi + 138 pp. Illustrated. $1.00. Williams and Wilkins.

The author, director of research for the Universal Oil Products Corporation, presents a popular outline of the history, importance and present organization of oil and the oil industry, with some detailed and technical material on oil geology and methods of extraction.

The Earth, the Seas and the Heavens. xiv + 238 pp. $3.00. Illustrated. Encyclopedia Britannica.

A collection of articles on physical geography, meteorology and astronomy, selected from the new 14th edition of the Encyclopedia Britannica. Contributions by the following authorities are included: Eddington, Jeans, Cornish, Stefansson, Crommelin, Dingle, Dyson, Greaves and Philips.

Phytopathological and Botanical Research Methods. THOMAS E. RAWLINS. ix + 156 pp. $2.50. Illustrated. John Wiley.

An attempt to develop new phytopathological and botanical experimental methods and to improve those described by other workers. The author discusses choosing and planning a research project; experimental methods, including microscopic, culture and virus studies; and the interpretation of experimental results.

Insects—Man's Chief Competitors. W. P. FLINT and C. L. METCALF. viii + 133 pp. Illustrated. $1.00. Williams and Wilkins.

How man and insects fight each other, what they fight about and why, is the burden of this book. The authors tell what an insect is and describe the lives and habits of several of the more common and important insect competitors of mankind.

The Story of Microbes. P. W. ALLEN. 454 pp. Illustrated. $3.75. Bookmill Company.

This is not a book of professional bacteriology, but is an orientation for lay readers and students who wish to link microbes with the other important affairs of life. The author is professor of bacteriology at the University of Tennessee.

Climbing Roses. G. A. STEVENS. 220 pp. $2.00. Illustrated. Macmillan.

A companion volume to "How to Grow Roses" by the secretary of the American Rose Society. The author discusses varieties suitable for various localities and uses, presenting not only the commercially well known but also those in the process of development.

American Red Cross First Aid Text-book. ix + 237 pp. Illustrated. Not for sale. Blakiston's.

To this revision of the official Red Cross text-book numerous medical and allied authorities have contributed material and advice, as have representatives of industrial firms whose work places them in contact with frequent situations requiring specialized knowledge of first aid.

The First Two Years. Vol. II. "Intellectual Development." MARY M. SHIRLEY. xvi + 513 pp. $3.00. Illustrated. University of Minnesota Press.

The second of three volumes presenting an account of the development of twenty-five babies observed from birth until the age of two years, with sections on the development of specific behavior traits, descriptions of psychological examinations and on the general principles evolved from the whole study.

THE SCIENTIFIC MONTHLY

AUGUST, 1933

THE SCIENTIFIC WORK OF THE BUREAU OF FISHERIES

By FRANK T. BELL

COMMISSIONER, U. S. BUREAU OF FISHERIES

THE aquatic life in our coastal waters, in our streams and in our lakes represents a national resource of great but frequently unappreciated value to every citizen of the United States. It supports a poorly organized industry made up in the main of numerous small and scattered units from which about 500,000 of our people gain a livelihood. It produces three and one fourth billion pounds of products that serve as highly nutritious and indispensable food for man and his domestic animals, ranking next to pork and beef as a source of protein, and provides raw materials for a score of industries. In the sea, and to a lesser degree in our interior waters, private ownership of fish does not begin until the catch has been made; fish life is the common heritage of a bounteous nature. Because of the migratory character of most of the important commercial species, which carries them beyond the boundaries of individual states, fishery problems are not only state but also national and international, the last of which is of growing importance. Their welfare is therefore properly the concern of the Federal Government.

The products of the commercial fisheries entering commerce can be gauged by economic standards; the total benefits derived from the fresh-water or sport fisheries are more difficult to evaluate. Some one has made the guess that every game fish is worth a dollar per pound. This may far underestimate the real value, for no one can determine from the huge total spent annually on outdoor recreation what portion is chargeable to the support of angling. Ten million fishing rods were manufactured and sold in 1932. Who can tell how many new automobiles were required to transport the fishermen? Who can estimate the spiritual values of improved health and mental balance induced by fishing?

The functions of the Bureau of Fisheries, the sole federal department concerned with the maintenance and wise use of aquatic resources, therefore, involve the promotion of trade and commerce in the products of the fishing industry, as well as the conservation of a natural resource upon which both industry and public recreation depend. Both of these major functions require the application of scientific principles no less than do the corresponding functions of other government departments which are concerned with the promotion of agriculture, forestry, the development and conservation of mineral resources and the promotion of trade activities. Hence, the Bureau of Fisheries may be classed with the technical and scientific Bureaus of the Government which under a broad interpretation of the police

THE BUREAU'S NEWEST FISHERIES BIOLOGICAL LABORATORY
AT SEATTLE, WASH., IS ADJACENT TO THE CAMPUS OF THE STATE UNIVERSITY. IT PROVIDES LABORATORY QUARTERS FOR THE BIOLOGISTS OF THE BUREAU ENGAGED IN STUDIES OF THE ALASKA FISHERIES AND THE MARINE FISHERIES OF THE PACIFIC COAST STATES, AS WELL AS THE STAFF OF THE INTERNATIONAL FISHERIES COMMISSION OF THE UNITED STATES AND CANADA ENGAGED IN INVESTIGATIONS AND CONTROL OF THE HALIBUT FISHERY OF THE NORTH PACIFIC.

powers of the state assure to all our citizens equal opportunity in the fullest enjoyment of inherited rights in their common property.

To appreciate the relations of the purely scientific functions of this Bureau to its administrative activities, a word may be said about the organization itself.

Organization

The Bureau of Fisheries owed its inception to the widely entertained opinion that the fisheries in general were diminishing in value and importance on account of the intensity and methods with which they were prosecuted. The American Fish Culturists' Association (now the American Fisheries Society) took a leading part in advocating an investigation of the subject, and largely through its influence and the representations of state fishery officers Congress passed a joint resolution, approved February 9, 1871, which provided for the appointment of a Commissioner of Fish and Fisheries, who was directed to conduct investigations concerning the facts and the causes of the alleged diminution and the feasibility of remedial measures. This was the beginning of one of the earliest and most effective conservation movements undertaken by the Federal Government.

Until July 1, 1903, the establishment was independent, reporting directly to Congress, and was known as the United States Commission of Fish and Fisheries, but on the organization of the Department of Commerce it was included by law in the new department and the name was changed to its present designation.

As now constituted the Bureau is concerned with the wise husbandry of our fishery resources. This includes the collection of biological and statistical data to reveal the condition and trend of the important fisheries; the development of the science of aquiculture as a means for improving fish cultural practises, and developing water farming on a commercial basis; the propagation and distribu-

tion of food and game fishes to replenish the natural supply; and the conduct of economic and technological studies to assure the wise use of the fishery harvests.

Acting in an advisory capacity, the Bureau has been able to exert a powerful influence on the fisheries legislation of the states. Local authorities and interests hold its work in high regard, and, appreciating that its advice is authoritative and disinterested, frequently seek it. Members of its staff are called on to serve with and assist state commissions and frequently to address state legislative bodies on topics connected with the administration of the fisheries and to assist in the drafting of state fisheries laws. It is also represented on commissions having to do with international fisheries questions of conserving the supply of aquatic animal life—fishes and mammals.

Formerly the Bureau was wholly without administrative or executive control of the fisheries, as these functions are vested in the several states within whose territorial limits the fisheries are located. By an order of the Secretary of Commerce, dated February 15, 1905, the Bureau for the first time was charged with the administration of the salmon fisheries of Alaska. Subsequently by law this jurisdiction was extended to all the fisheries of Alaska. On December 28, 1908, the Alaska fur-seal service, which since the formation of the Department had been administered through the Secretary's Office, was transferred to the Bureau. By act of Congress in 1906 the Department became charged with the duty, which is also exercised through the Bureau, of controlling in certain respects the sponge fishery prosecuted on the high seas off the coast of Florida.

The Bureau has a staff of 78 persons attached to the central office at Washington and a field service of 466, not including temporary per diem employees. Its work is organized under five divisions, the Division of Administration, the Division of Fish Culture, the Division of Inquiry Respecting Food Fishes ("Scientific Inquiry"), the Division of Fishery Industries, and the Division of Alaska Fisheries, which latter is divided into the fur-seal service and the fishery service. Two of these divisions are directly engaged in scientific investiga-

THE BUREAU'S RESEARCH VESSEL "BLACK MALLARD"

IS OPERATED BY THE LOUISIANA DEPARTMENT OF CONSERVATION FOR THE PURPOSE OF COMBINING SCIENTIFIC STAFFS OF THE TWO ORGANIZATIONS IN A COOPERATIVE INVESTIGATION OF THE LIFE HISTORY, HABITS AND CONSERVATION REQUIREMENTS OF THE SHRIMP OF THE SOUTH ATLANTIC AND GULF COASTS. HERE EXPERIMENTAL HAULS WITH A COMMERCIAL SIZE SHRIMP TRAWL ARE BEING MADE IN BARATARIA BAY, LA., TO PROVIDE DATA REGARDING THE SHRIMP POPULATION OF THAT IMPORTANT FISHING GROUND.

THE BUREAU'S FLOATING LABORATORY IN THE MISSISSIPPI VALLEY

QUARTERBOAT 348 IS HERE BEING MOVED UP THE TENNESSEE RIVER BY THE ARMY ENGINEERS' STEAMER FOR A THOROUGH LIMNOLOGICAL SURVEY, WHICH WILL FORM THE BASIS OF RATIONAL CONTROL AND DEVELOPMENT OF AQUATIC LIFE IN CONNECTION WITH PENDING REFORESTATION, FLOOD CONTROL AND HYDROELECTRIC DEVELOPMENT PROJECTS IN THAT GREAT RIVER VALLEY.

tions. Studies of a more strictly biological nature concerned chiefly with problems of the supply of the food and game fishes and its maintenance in a state of highest productivity are handled by the Division of Scientific Inquiry, while those of a technological or economic nature concerned with the proper utilization of fishery products and the dissemination of trade information are conducted by the Division of Fishery Industries.

Scientific investigations are prosecuted at a large number of permanent and temporary field stations. In addition to the laboratories in the Department of Commerce Building in Washington, four permanent fisheries biological laboratories are operated, two on the Atlantic Coast, at Woods Hole, Massachusetts, and Beaufort, North Carolina, respectively; one in the Mississippi Valley at Fairport, Iowa, and one at Seattle, Washington.

Field stations are operated cooperatively with the states at Milford, Connecticut, Brunswick, Georgia, New Orleans, Louisiana, and Olympia, Washington. The Bureau owns two experimental fish cultural stations, one at Pittsford, Vermont, and one at Leetown, West Virginia, and cooperates with the State of New York and Cornell University in the operation of the experimental hatchery at Cortland, New York.

Field headquarters are also maintained at various universities throughout the country where excellent laboratory and library facilities are furnished. These universities include Harvard, Yale, University of Michigan, University of Missouri, University of Utah and Stanford University. In addition to the well-equipped fishery products laboratory in Washington, temporary technological laboratories are established at important fishing ports in accordance with local needs, the largest of which has been operating for more than two years at Gloucester, Massachusetts.

Until the beginning of the present fiscal year, the Bureau has operated a number of vessels, launches and floating laboratories in the conduct of its scientific investigations. Various phases of the North Atlantic fishery investigations have required the full time of the *Albatross II*, a 150-foot steam vessel, equipped for oceanographic work and experimental trawling. Fishery studies

in Lake Michigan have been prosecuted from the motor ship *Fulmar*, a 102-foot vessel, equipped for experimental fishing and limnological study. On the Mississippi River two houseboats and various launches provide laboratory and collecting facilities; one, an 85-foot quarterboat, has a large and well-equipped physiological and chemical laboratory and accommodations for a dozen workers. In Alaska a 45-foot launch is used exclusively for herring investigations and various others of the Bureau's large fleet of vessels are employed as circumstances warrant.

Biological Investigations

The major scientific projects of the Division of Inquiry are included in three fields: marine and fresh-water commercial fishery investigations, investigations pertaining to game fishes and shell-fishery investigations. The study of the marine and fresh-water commercial fisheries is properly classified and is now generally recognized as a distinct branch of science variously known as fishery biology or fishery science. The problems encountered in the promotion of shellfish culture and the growing of food and game fish for stocking interior waters are included in the rapidly expanding field of aquiculture.

Doubtless the most significant and fundamental problems affecting the supply of raw materials to the commercial fisheries are overfishing, fluctuations in abundance and management of the supply. Although many people still believe implicitly in the inexhaustibility of the resources of the sea, in which views they are upheld by contemplation of the vast areas of waters, the tremendous fecundity of aquatic animals and the antiquity of the great sea fisheries, the fear of depletion of the more valuable species by commercial fishing has been the foundation of all governmental activity in connection with fishery investigations. That these fears were not ill-founded is amply proved by experience and, in a few cases, by sound scientific investigation. We need only look back over the statistical records of such fisheries as the Atlantic salmon and halibut, the shad and alewife in the coastal rivers of the Middle Atlantic States and in New England, and the sturgeon in these rivers and in the Great Lakes to be convinced that disaster can overtake such fisheries as the inevitable result of intensive or destructive fishing, which, in some cases, is coupled with the pollution of waters or the obstruction of spawning beds.

It is true that coastal and anadromous fishes, being within easy reach of the fishermen's nets or, because of their peculiar life history, actually assembling in mass and coming to the fisherman's very door to be caught, are more vulnerable than the pelagic forms, but even deep sea fisheries are subject to serious reduction as is evidenced by the fate of the Pacific halibut and by the history of the plaice fisheries of the North Sea.

Depletion in the commercial fishery is usually understood as a decline in yield per unit of effort, but a reduced level of supply in any species may be the result of a vast complex of natural causes and not solely the result of overfishing for great variations in abundance have been observed in nature which are in no way related to depletion. Overfishing, therefore, may not be judged alone by an absolute decline in the numerical strength of the fish population in any area, for biological criteria of depletion exist that must be taken into account.

One of the major objectives of the Bureau's biological investigations is to discover the earliest signs of depletion of the supplies of commercial species before total landings have declined to such an extent that commercial fishing operations are no longer profitable and before depletion has become so extensive that the very existence of valuable food supplies is threatened. The security of

AT THE FISHERIES BIOLOGICAL STATION, FAIRPORT, IOWA

STUDIES ON INCREASING THE PRODUCTION OF WATER AREAS THROUGH FERTILIZATION TO INCREASE PLANKTON GROWTH HAVE RESULTED IN PRACTICAL IMPROVEMENTS IN BASS CULTURAL METHODS. THIS HAS INCREASED THE YIELD OF THE EXPERIMENTAL PONDS FROM 5,000 BASS PER ACRE, WHICH A FEW YEARS AGO WAS CONSIDERED SATISFACTORY, TO MORE THAN 20,000 PER ACRE. HERE THE CREW IS REMOVING THE BASS FROM AN EXPERIMENTAL POND AT THE END OF THE GROWING SEASON. THE MAIN LABORATORY IS SEEN IN THE BACKGROUND.

large investments in gear, vessels, factory equipment and the entire machinery of preparation and distribution, as well as the livelihood of thousands of people directly or indirectly dependent upon the fishing industry for support, can only be assured by continued vigilance on the part of the responsible governmental agencies entrusted with the conservation of national wealth and well-being.

The expression "fisherman's luck" summarizes the fact that the yield of the fisheries both locally and over wide areas is extremely erratic and a great mass of scientific evidence now available indicates that these changes in yield are primarily caused by major fluctuations in the actual abundance of the various fish stocks. Such variations in abundance are also found in land animals, and attempts have been made to discover cyclic changes related to worldwide factors such as solar variations and the like.

The study of these fluctuations in abundance forms the major activities of the biologists of the Bureau of Fisheries in the North Atlantic area and is being applied to the haddock, mackerel, scup and weakfish. There can be no doubt that this general principle applies to the supply of all fishes, but probably the most spectacular variations are found in the mackerel fishery which has been studied for several years.

From a study of the age-composition of the commercial catch of mackerel, together with the records of landings, data have been secured which indicate that some year-classes are produced in great abundance. On the basis of these studies in which the relative strength of the various year-classes is calculated, together with their rates of decline, predictions of the expected yield have been offered for several years. These predictions have great potential value to the fishing industry. If a season of unusual abundance may be foreseen, marketing channels may be prepared for expanding distribution, and the technological proc-

esses, such as freezing, salting, canning and packing, may be planned to take care of the excess production, thus preventing glutted and demoralized markets, which too often drive prices so low as to cause real distress among the fishermen. Conversely, in seasons when scarcity appears inevitable, the cost of such preparations can be saved and accumulated stores of processed fish may be released to supplement current production. Predictions have, therefore, been released, first made public in fishing and trade journals and later by Bureau publications.

Although no reports have been published, similar predictions have been prepared for several years for the major runs of salmon in the important fishing districts of Alaska. Strangely enough these predictions are based on less precise data than are available for the pelagic sea fisheries. They include such factors as the known escapement of spawning salmon and their age-composition, the physical conditions upon the spawning beds, the estimated production of young salmon migrating seaward, the normal age at maturity and various other indications such as, for example, in the red salmon, the number of grilse or precocious males returning in the year previous to the year of prediction and which are believed to bear a fairly definite relation to the number of normally maturing adults. These predictions are becoming increasingly accurate and already have provided such valuable information for the salmon canning industry that they are accepted as an important basis for the regulation of the fisheries by the Government and for the commercial preparations for packing activities the ensuing year. There is no doubt that additional research along these lines will bring still closer the practical control of fishing operations and the maintenance of the stock of fish.

From the investigations of the haddock fisheries off the New England coast it is becoming increasingly evident that success or failure of the great trawl fishery, employing nearly 100 of the largest vessels in the fishing fleet, depends upon success or failure of spawning and survival of the young and not directly upon the numbers of spawning adult haddock. The decline of the haddock fishery from its maximum in 1929 to a minimum in 1932 is thus attributed to failure of reproduction in the years from 1926–28. Improvement in the yield is anticipated because of the relatively successful spawning year of 1929 which produced more young haddock than any year since 1924.

For the first time the mystery which has shrouded the life history and habits of the shrimp on the South Atlantic and Gulf Coasts is yielding to scientific research. Although the investigation started as recently as 1931, the extreme vulnerability of the shrimp supply to overfishing has been demonstrated. Because of the fact discovered during the year that the important commercial species have a life cycle limited to about one year, warning has been issued to the states that the fisheries should be diligently observed for first signs of depletion, which when it appears will almost certainly run a tragically rapid course resulting in disaster for this extensive industry. The major features of the life history of the shrimp have been sketched as a basis for wise conservation measures when they are needed.

Investigations of the important commercial fisheries of the Great Lakes during the past year have been concerned almost wholly with the abundance and distribution of the various species of food fishes and the effects upon the fish populations of the various types of commercial fishing gear. Although the yield of the commercial fisheries in these waters has been maintained in the aggregate for several decades, it is gen-

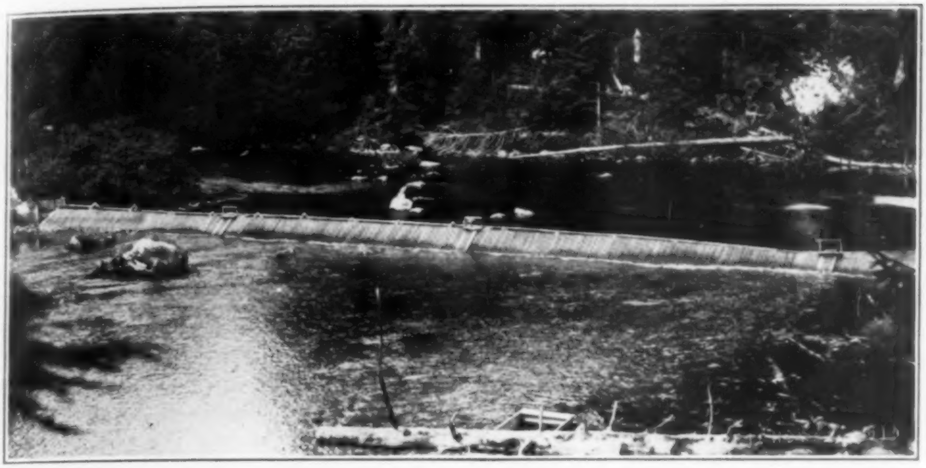
ON THE SHORES OF LITTLE LAKE

A TRIBUTARY OF BARATARIA BAY, LA., 30 MILES FROM THE GULF, THE BUREAU'S INVESTIGATORS HAVE DISCOVERED AN IMPORTANT NURSERY GROUND FOR MINUTE YOUNG OF THE IMPORTANT COMMERCIAL SPECIES OF SHRIMP. BY SUCH PERSISTENT EFFORTS THE LIFE HISTORY OF PENAEUS HAS BEEN TRACED FROM ITS SPAWNING IN THE GULF OF MEXICO, ITS MIGRATION INTO FRESH WATER AND ITS RETURN TO THE GULF FOR SPAWNING AND DEATH A YEAR LATER.

erally known and recognized that depletion of the important species is occurring with greater rapidity in some lakes than in others, and that total production has been maintained by the substitution of less valuable species for the ones that are more valuable and better known. The efforts of the Bureau's technical staff at present are directed toward the correction of abuses in the commercial fishery and especially the reduction of the tremendous wastage of immature and undersized fish that annually reaches impressive proportions.

During the past few years the Bureau's investigations in aquiculture have been successful in improving hatchery technique, combatting disease which annually takes heavy toll of trout and other game fishes crowded under unnatural conditions in hatchery troughs, and in improving strains of brood fish that are more productive and more disease-resistant than wild stock. Improvements are constantly being made in developing diets that will produce growth, vigor and color in hatchery-reared fish equal or superior to those found in nature. At the same time material economies in operation have been effected by the use of cheaper food materials.

Improvements in the restocking of inland waters are resulting from the Bureau's program of stream survey. The extension of highway travel and the rapid increase in the number of anglers have necessitated radical changes in the methods of planting and have demonstrated the necessity for systematic stocking based upon accurate knowledge of conditions of fish life existing in the more accessible lakes and streams. Since the Bureau's responsibility for maintaining and improving angling is definitely indicated in the waters of the public domain, limnological investigations have been concentrated in the national parks and forests in the intermountain region and will be extended to other areas as funds and personnel permit. Studies already made under this program are yielding results in systematic stocking of public waters that will be increas-



THE SALMON WEIR AT ANAN CREEK IN SOUTHEASTERN ALASKA IS TYPICAL OF A CONSIDERABLE NUMBER OF SUCH STRUCTURES PLACED IN THE MORE IMPORTANT SALMON STREAMS OF ALASKA FOR THE PURPOSE OF COUNTING THE NUMBER OF SPAWNING FISH THAT ASCEND THE RIVERS. ENUMERATORS STATIONED AT THE GATES IN THE WEIR TALLY EACH FISH OF THE VARIOUS SPECIES COMPRISING THE SPAWNING RUNS, WHICH UNDER THE WHITE ACT OF 1924 MUST EQUAL THE NUMBER OF FISH TAKEN BY THE COMMERCIAL FISHERIES AT THE MOUTHS OF THE RIVERS. IN ADDITION TO THE IMMEDIATE PRACTICAL CONTROL OF FISHING OPERATIONS THE DATA THUS OBTAINED HAVE GREAT SCIENTIFIC VALUE.

ingly apparent to the angler from year to year.

Investigations concerning various problems of the oyster industry were carried out in New England and the North Atlantic states, South Atlantic states and on the Pacific coast in Washington and California. The selection of specific projects of study in different sections of the country was governed both by the local conditions and most urgent needs of the industry. Thus, in New England and the North Atlantic states, where previous work of the Bureau materially helped in the solution of the problem of propagation of the oyster, the main efforts were directed to a study of the methods of growing, fattening and improving the nutritive quality of oysters. On the other hand, in the South Atlantic states where the depleted condition of the natural oyster reefs threatens the existence of the industry, principal attention was given to the methods of restocking and maintaining the productivity of the bottoms. On the Pacific coast the work consisted in studies of the cultivation and development of the native Olympia oyster.

Because of their close association, the Bureau has investigated simultaneously problems concerned with the propagation and conservation of the fresh-water pearly mussels of the Mississippi Drainage and pollution of these waters by industrial and sanitary wastes and silt. Despite closed seasons and various restrictions on the mussel fishery, the supply has declined seriously in recent years and efforts at restocking have failed because of the tremendous increase in the load of silt carried by the rivers, which in turn render the increasing volume of municipal wastes more and more destructive of life in polluted waters. From careful limnological surveys of the greater portion of the principal streams in the Mississippi Drainage it has been found that the uncontrolled introduction of silt into

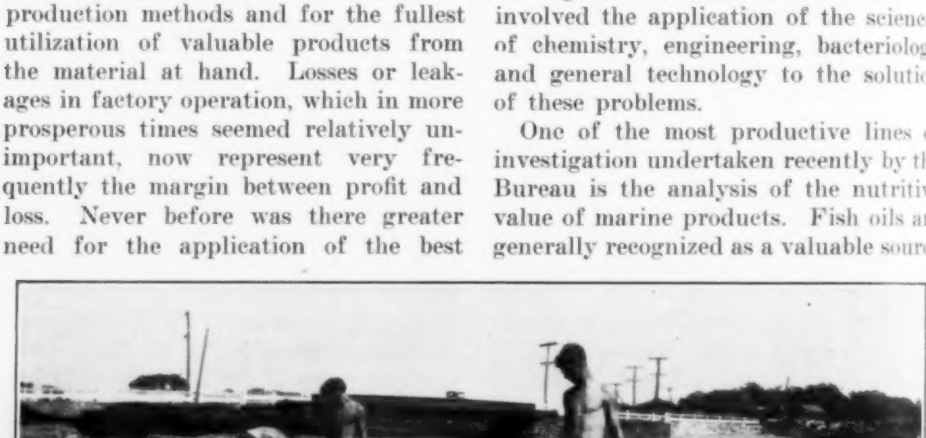
these streams has increased tremendously the areas disturbed by the major pollution centers of the great cities.

Since such silt makes it impossible for the streams to rid themselves of the huge volume of organic wastes now being poured into these waters, the pollution problem has become so serious that aquatic life has been practically reduced to those few undesirable forms capable of surviving in highly polluted waters. The combined pollution is spreading with amazing rapidity, menacing alike the mussel resources and the food and game fishes.

Technological Investigations

Never before in the history of the fishery industry of this country has there been greater need for economy in production methods and for the fullest utilization of valuable products from the material at hand. Losses or leakages in factory operation, which in more prosperous times seemed relatively unimportant, now represent very frequently the margin between profit and loss. Never before was there greater need for the application of the best technological and engineering knowledge available to problems of manufacture, preservation and marketing of marine products than at present. This is absolutely essential to make the most of the raw material available, to eliminate waste, and to bring factory operation to the highest point of efficiency. With this objective in mind, the technological research of the Bureau has followed the general lines of studies of methods of manufacture, preservation, storage and marketing of both the primary products of the fisheries for food and the by-products for animal nutrition, biochemical tests to determine the food value of marine products, the development of fishing gear, and experiments in developing chemical treatments of fishing nets to lengthen their useful life. This has involved the application of the sciences of chemistry, engineering, bacteriology and general technology to the solution of these problems.

One of the most productive lines of investigation undertaken recently by the Bureau is the analysis of the nutritive value of marine products. Fish oils are generally recognized as a valuable source



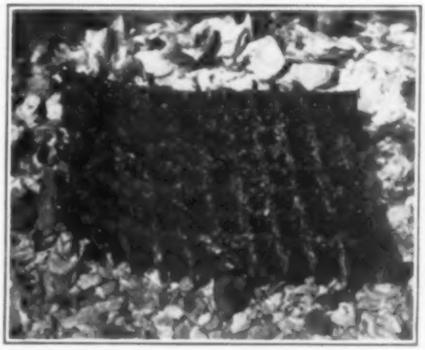
THE SHALLOW BAYS OF CONNECTICUT AND RHODE ISLAND

ARE THE MOST IMPORTANT PRODUCTION CENTERS FOR SEED OYSTERS, SUPPORTING THE GREAT OYSTER FARMS OF LONG ISLAND SOUND, ALTHOUGH RELATIVELY FEW YEARS IN A DECADE PRODUCE GOOD CROPS. THE BUREAU'S CREW IS HERE PLACING ARTIFICIAL COLLECTORS TO CATCH OYSTER SPAT TO DETERMINE THE BEST MEANS OF INCREASING PRODUCTION.

of vitamins important in the diet, and the supply has been obtained chiefly from the liver oils of the cod and cod-like fishes. Recent investigations, however, have demonstrated that other species contain in some cases greater quantities of vitamins A and D than cod-liver oil. One of these is halibut liver oil which is at least 50 times richer in vitamin A than medicinal cod-liver oil. Salmon liver oil has been shown during the past year to be 10 to 12 times as potent in vitamin A. However, difficulties in extraction of this oil have prevented its general use, and study is being given to this question. The discovery of high vitamin potency in sardine oil has tremendously expanded the market for this domestic product in poultry feeding at a great economic gain to our producers and farmers.

It has also been known for many years that shell-fish properly prepared were likewise richly supplied with various vitamins important in a balanced diet. Sound investigations by the Bureau's staff in cooperation with other food research agencies demonstrate that oysters, because of their unusually high content of copper and iron in organic combination, are particularly valuable for combatting nutritional anemia. Oysters from different localities on the Atlantic and Gulf Coasts, while differing in their iron and copper contents, were fed to anemic animals and all induced marked regeneration of hemoglobin, thus giving further evidence of the importance of oysters as a source of iron in addition to their other food factors.

Technological and engineering studies have also been undertaken upon problems of properly preserving and handling fishery products and by-products in order to assure their highest quality at the time of delivery to the consumer. Such studies have been made as to the determination of proper storage temperature for frozen fish that will permit the least evaporation and that will retard the action of enzymes that result in gradual spoilage of the product. The technique of freezing and storing of several species of shell-fish has been given consideration including the proper temperature of freezing, the most efficient temperature for storage, the effects of defrosting, and the rate of spoilage after defrosting. Improved methods have been devised for smoking fish in which proper temperature, humidity and the composition of the preserving agent have been found to be important.

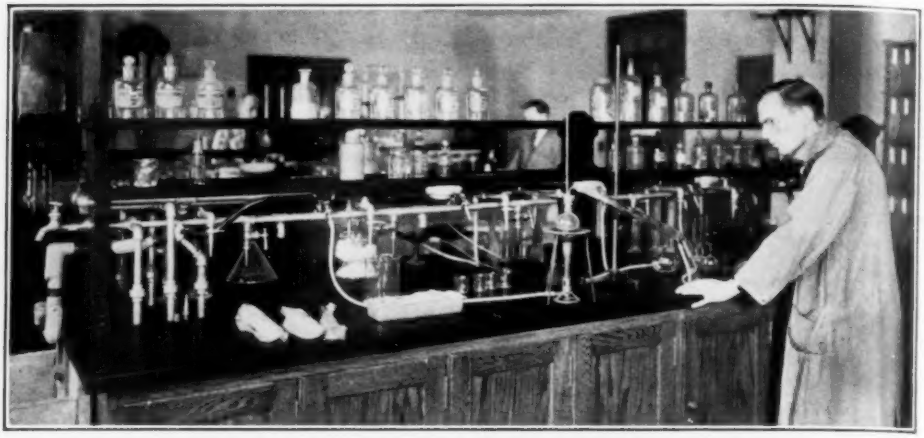


CARDBOARD MATS LIKE EGG CRATE PARTITIONS

COATED WITH A THIN LAYER OF CEMENT, HAVE BEEN DEVELOPED BY THE BUREAU AS A MOST EFFECTIVE OYSTER SPAT COLLECTOR. THIS COLLECTOR EXPOSED ON THE FLATS IN MILFORD HARBOR, CONN., OBTAINS 100 TIMES MORE YOUNG OYSTERS THAN COULD BE COLLECTED BY THE OYSTER SHELL CULCH USUALLY EMPLOYED. THE COLLECTOR WILL BE CRUSHED AND THE PIECES PLANTED IN DEEP WATER WHERE FINE SINGLE OYSTERS WILL DEVELOP WITHOUT CROWDING.

Bacteriological studies on processes of preservation have been undertaken. As a result of these studies objective tests for the freshness of fishery products have been devised which correlate chemical reactions with bacterial counts of the flesh and which give promise of having wide application to the fishing industry.

In most industries the income from the marketing of the major products pays only for the expense of operation and production; profit is frequently de-



THE TECHNOLOGICAL LABORATORIES OF THE BUREAU OF FISHERIES
IN THE NEW COMMERCE BUILDING AT WASHINGTON, D. C., ARE WELL EQUIPPED FOR CHEMICAL ANALYSES, PHYSICAL DETERMINATIONS AND TECHNOLOGICAL EXPERIMENTS IN THE HANDLING OF FISHERY PRODUCTS. THE NUTRITION LABORATORY ALSO MAINTAINS A RAT COLONY OF STANDARD STOCK FOR BIOLOGICAL ASSAYING OF THE VITAMIN AND NUTRITIONAL VALUES OF FISH MEALS, OILS AND OTHER PRODUCTS OF THE MARINE FISHERIES.

rived primarily from the marketing of the by-products. Because of antiquated methods and the decentralization of supplies, possibilities in this direction have never been realized by the fishing industry. Considerable attention has been given, therefore, by the Bureau's staff to the by-products industry in the fisheries, and extensive studies of an engineering and technological nature have been conducted on perfecting methods for manufacturing fish meal from the non-oily fish wastes and meal and oil from menhaden and other oily fishes.

Conversion of wastes derived from the preparation of packaged fishery products has an important bearing on the fishing and agricultural industries. The conversion into a useful product, fish meal, brings added revenue to the fishing industry, and to agriculture one of the most highly nutritive protein concentrates obtainable. As a service to these industries, it is important that the fundamental factors of manufacture, as related to the preservation of nutritional values, be understood fully, and further it is of primary importance to obtain information as to the most economical means of obtaining this end. Biological tests of the products have demonstrated that the digestibility, vitamin value and general nutritive value are affected by drying, by temperature of drying and the method of applying heat. The details of the most effective means of preparation will be released for industrial use.

Various other studies of an engineering nature have been conducted; one of importance concerns improved methods of preserving net materials. The deterioration of cotton webbing used in fish nets entails a heavy financial loss to the fishing industry annually, which can be largely reduced by chemical treatment of the fabric which prevents bacterial invasion, oxidation of the fiber and the fouling by marine growths.

STATISTICS OF THE FISHERIES

If wise conservation measures are to be enacted to perpetuate the fish population, if the element of "luck" in making the catch is to be removed, and if the fishing industry is to be supplied with

trade and market or distribution statistics, it is necessary that figures be collected on various activities of the fishing industry. These should show not only the yield of the fisheries according to species and locality and the manufactured products, but if sufficiently extensive should provide a fairly accurate index of relative abundance of fish in the sea. This is the aim of the statistical investigations of the Bureau of Fisheries.

In former years the various geographic sections of the country were canvassed by enumerators at irregular intervals. Recently, however, it has been possible to obtain for each year a comprehensive record of the total quantities of fish landed during the previous year so that annual statistics of the aggregate yield of the fishery are now available.

Four main types of statistical surveys are conducted by the Bureau. These are (1) the general canvasses, (2) canvasses of landings at certain important fishing ports, (3) canvasses of special fisheries, and (4) canvasses of the industries marketing or manufacturing fishery products. In the general canvasses figures are obtained on the catch of the various species and their value as landed by the fishermen, the quantity or number of each kind of gear used, the locality of capture, and the number of fishermen employed, the number of fishing boats and the net tonnage of fishing and transporting vessels. Statistics are collected also on the activity of plants, manufacturing and marketing products, including annual catch, the number of wholesale establishments and other economic data regarding wages, number of employees, and products canned, smoked, salted, packaged or frozen. These figures are tabulated at the Bureau and are issued monthly or at short intervals in order to provide prompt information to the industry.

Recently Dr. Julius Klein, former Assistant Secretary of Commerce, stated, "Future existence will be connected more and more with conceptions based on statistical information." To form a basis for conceptions of the fishing industry as a guide to commerce, the Bureau is endeavoring to supply adequate statistical data on the potential supply, the production and the distribution of fishery products.

THE MAYA AND MODERN CIVILIZATION

By Dr. ROBERT REDFIELD

DEPARTMENT OF ANTHROPOLOGY, UNIVERSITY OF CHICAGO

RESEARCH ASSOCIATE, CARNEGIE INSTITUTION OF WASHINGTON

THE name "Maya" is so generally associated with ancient ruins and the mystery of a departed people that, before setting forth certain research plans of Carnegie Institution of Washington, it should perhaps be stated that the Mayas are not extinct. In fact, Maya Indians still constitute the largest element in the population of present-day Yucatan. The blood of the race that built the old cities predominates in the persons of several hundreds of thousands of men and women now alive. The Maya language, probably not very different from that spoken by the Indians who built Coba and Uxmal, is still the general language of communication outside of Merida, the capital of the present Mexican state of Yucatan. In fact, speeches in that language on such subjects as socialism, or the reasons for the economic depression, are delivered almost every day.

But these Mayas are not a vestige of a disappearing primitive tribe, melting away with the coming of civilization, like some of the Oceanic peoples. They are racially intermixed with Spanish whites; and they are not destined to extinction, but are to become one part of modern world civilization. And the process of so becoming involves a number of scientific problems for the student and of practical problems for themselves. As communications develop, as roads are built, schools multiply, moving-picture theaters are introduced and newspapers are read, the primitive and illiterate Indians of the hinterland undergo great social changes; and cor-

[1] Some of the illustrating photographs were taken by Alfonso Villa and some by the author.

THE SCHOOL AT CHAN KOM

responding changes take place among the whites and mixed bloods of the city.

These are the problems that interest us in carrying on work in social anthropology in Yucatan.[2] What ought to be done about the practical problems is not our immediate concern, but if anything can be found out as to how changes of this sort take place, such knowledge can by others be made of practical use. Some of us regard it as the function of scientific activity to enable people better to understand and to deal with the world around them. Society thinks this way about it too, I believe, for although individual scientists often (and rightly) carry on their work for its own sake, yet society supports science in the hope and belief that its activities may help men to get about in the increasingly intricate paths of living. It is natural that of those who have the ultimate serviceability of science in mind, some should choose to submit men's own ways to scientific observation and description, the better to understand their nature, their characteristic forms and manifestations. Human activities are the most immediate and important of natural phenomena.

Ethnological work among the Indians is often done because the student wants to find out what those Indians were like before the white man came, and how Indian civilization arose and developed in aboriginal America. This is also what the archeologist is engaged in investigating, and it is certainly a fascinating inquiry. Such historical studies add to the content of our knowledge; when they give us insight into how life looked to these ancient people, to an extent we have through them experiences never actually ours. Such knowledge of other people's lives is like an education in the humanities. In studying the customs of present-day peoples, the knowledge one gets is much the same sort. But some students wish to reduce this knowledge to types, to treat cultural behavior as a natural phenomenon with its characteristic and recurrent attributes. There is in such students the desire to know how customs and institutions arise, take form and change form.

It may be said that historical accounts of Maya culture origins throw light on this question, but to this it may be replied that the archeological account of culture changes is often lacking in detail. Sometimes it is no more than a statement as to tribal migrations, and as to cities founded and abandoned. In the details of social change, the precise circumstances under which men come to alter their ways, the little events that initiate changes—in respect to these the archeological record is necessarily deficient. At any rate, the flow of life is better observed in all its richness when it is flowing; recovery of the flow by historical inquiries after it has passed yields a less full and intimate body of materials. Thus, though the social anthropologist joins hands with the archeologist in a common interest in the Maya, and eagerly appropriates what he can tell of the events that led up to their present social organization, he must derive most of his materials from direct observation of contemporary culture in its eternal making and re-making.

This kind of observation may be made, one properly suggests, anywhere that social changes are going on, without the necessity of a trip to Yucatan. This is true, but there are certain reasons for welcoming the opportunity, given by Carnegie Institution, to express this interest in the Maya field. There are more immediate reasons arising from the facilities afforded by the institution, and from the presence in the Yucatan peninsula of scientific workers

[2] The project outlined in these pages is promoted by Carnegie Institution of Washington; by an arrangement with the University of Chicago, the writer is enabled to devote part of his time to it.

of different yet related interests. There are also reasons arising from the nature and distribution of culture and civilization in Yucatan.

That peninsula, virtually an island by reason of the natural barrier to communication formed by the tropical forests of the south, contains within it a short outline of civilization. For its inhabitants represent the range of social development from the primitive tribe to the modern city. There are Indians in the south who use the bow and arrow and follow entirely pagan and aboriginal religions, there are city dwellers in the capital who do business in the credits of international finance and whose interests are cosmopolitan, and there is every intermediate degree of sophistication.

Nor are these various cultures static: they are all changing under the influences of that expanding system of industrial civilization which we call "Western," but which is no longer confined to any one quarter of the earth. South African hemp fibers compete with the sisal of Yucatan, and the price of labor in Africa is a matter of importance to the Maya Indians. Other Maya, in the less accessible forests of Quintana Roo, have changed their mode of living in response to the demand for chewing gum fomented by modern advertising in cities of which they have never heard, but of which, as another result yet to come, they will one day hear.

The great spread of trade, machines and communications effects the important changes of to-day, that in our own country and in western Europe take the form of the expansion of the metropolitan area and its zone of influence, and that in the wider world bring about the breakdown or reorganization of the primitive and the "medieval" societies. The widening circles of industrial civilization reach all the "backward peoples" and bring them a leaven of unrest. Of changes of this latter sort those going on in Yucatan are an instance; the country is relatively near our own, and we have been given the opportunity to observe and report on these changes as they are taking place.

THE OLD STYLE MAYA HOUSE

THE NEW STYLE HOUSE—CHAN KOM

One stands a good chance of improving the methods for making such studies anywhere, in the attempt to make one such study in Yucatan. At any rate, in so defining our problem we may hope to do a little more than collect information on the customs of the Maya Indians. Advance in science is marked not so much by how much more you know as by what new and better ways you have for knowing.

The plan of study in Yucatan, entirely tentative and experimental, is the simultaneous study by similar methods of sample communities along the range of civilization that exists in Yucatan. We can not study every community, but we can select those that we do study so that they represent stages in this course of change: we can study an isolated and primitive bush village, another village of people with a similar cultural heritage but who have had schooling and opportunity to communicate with the towns, a third community (near the city) of wage earners who go to the city and to the movies; and we can make studies in the capital city itself. Such studies, if carried on in the same terms, should yield a comparison that would roughly represent the process of civilization, or urbanization. At least it should suggest some of the ways in which the stable societies of non-literate people, dependent on a local tradition, give way to the more mobile and individuated society of the modern city.

In furthering this plan we have done some preliminary work in the city of Merida, and we have entered upon a study of one community, a village named Chan Kom, situated in the southeastern part of the state of Yucatan not far from the archeological site of Chichen Itza.

Chan Kom is a place about in the middle of the scale of civilization in Yucatan: there are other communities less civilized and others more so. It lies on the outer margins of the area controlled by the state government and affected by roads and schools. Its two hundred and fifty people, all Maya, were practically all born and brought up in the neighborhood. All are familiar with the nearest town on the railroad, many have been to the capital city, but only one or two have ever lived there. Maya is the universal language of ordinary conversation, but about one

fifth of the people also speak Spanish. About as many can read and write, but only a very few do. All grow the corn and beans that they eat, but each man produces more than his family consumes, for part of the crop must be exchanged for textiles, salt, gunpowder and other necessaries which the factories manufacture and sell to the villagers chiefly through itinerant merchants.

Practical activities are closely associated with magical and religious observances. A simplified ritual form of Catholic Christianity exists along with a pagan religion derived historically from that practised by those ancient temple-building Mayas. The planting and harvesting of corn is sanctified by ritual offerings, sometimes highly ceremonial, to the gods who bring the rain and guard the cornfield. Sacred breads are made and dedicated; turkeys are strangled with ceremonial bark beer. The beehives, too, have their special deities and appropriate propitiatory ceremonies. Shamans maintain this ritual, and divine the outcome of sickness or enterprise through crystal-gazing or the counting of grains of corn; but their prestige is waning, and it is shared by the authority of secular leaders who read the newspapers, study horticulture and commit their people to a program of modernization and progress.

The graver problems of life are still regarded as magically caused; sickness, for example, is thought to be produced by evil spirits embodied in the winds, or by the gods who punish failure to propitiate them when the corn is planted or the honey taken from the hive, or by the souls of dead relatives for whom the appropriate ritual has not been performed, or by the enchantments of the sorcerer in the next hamlet. Yet to-day in this village there is always an alternative treatment to that recommended by the shaman: the sick man may send for medicines from the drug store in the town, or he may go for treatment to the modern clinic established by Carnegie Institution at Chichen Itza.

Reference to tradition is still the predominant way to solve difficulties, but it is no longer the only way; the people are becoming used to novelty and experiment. There are plans to establish a cattle cooperative, the advantages of domestic hygiene are stressed in village discussions, there is some experiment in crop diversification, and a road is being built to connect the village with a railroad and the tourist trade. In this village an account of customs means little, unless it is also an account of how these customs are changing.

Our work here has been carried on with the important aid of Mr. Alfonso Villa, the school teacher, who has spent over two years in the village and has learned the Maya language. It has reached the point where acquaintance with the life is sufficient to suggest some of the problems that might be studied.

We have a fair account of the principal patterns of activity. We have familiarity with the cadences of life, the ways in which birth and marriage and death are met, and with the ceremonies which mark the rhythms of the agricultural year. The primitive economics of the village has been investigated: we know how much labor goes into raising how much corn, and how much corn is consumed, and how much sold. And we are beginning to have some inkling of the ways in which social changes came about in Chan Kom.

We have in this village the advantages of a situation that is relatively simple. Chan Kom is large enough to include forty or more households and individuals exhibiting a great variety of personalities, but small enough so that it is possible to have some acquaintance with everybody. Only two or three

people leave the village daily, and no more arrive. These arrivals and departures are almost the only means of communication with the outside world, and as novel and interesting information is quickly gossiped about, it is possible to observe the effect of such information on attitudes and practises.

So we have found ourselves experimenting with what might be called a genetic method for the study of social change. The effect of news and of internal events is watched over a period of time. For twenty months Mr. Villa has been keeping a journal, reporting the happenings in the village that have come to his attention. This is now a body of interesting episode, suggestive of what might be studied more carefully, but requiring some more objective and controlled techniques of observation. These episodes are sometimes matters of merely passing interest, but sometimes they involve changes in practises and standards of life. A man goes to the town, and hears a speech about the advantages of socialism and rational living, in which the orator urges the propriety of having two wives, provided only the husband can support them. The villager returns and puts the suggestion into practise; his first wife is enraged and the village is indignant. The man's prestige and patience overcome these difficulties; the new arrangement becomes accepted; after a little other men follow his example and several bigamous households are set up.

A young girl, in response to suggestion from the town and in defiance of custom, leaves her home to take employment in the town as a domestic servant. But her parents have already made arrangements for her marriage; they try to make her return to fulfil the contract, but fail; and the parents of the boy to whom she has been betrothed demand from the girl's parents the value of the food they have supplied for consumption during the ceremonial visits leading up to the betrothal. This claim is supported by the village authorities. The whole matter is discussed by every one; the other girls are particularly interested. But beyond this we can not at present follow the affair. What is the effect upon the younger generation of this first successful instance of a girl becoming independent of parental authority and support?

TOWER ERECTED AT CHAN KOM
TO ENABLE THE PEOPLE TO SEE THE RUINS AT CHICHEN AND SO TO LAY OUT THE LINE OF THE ROAD TO CONNECT THEM WITH THE RAILROAD AND THE CITIES.

Two difficult questions must be answered before material of this sort can be proved to be of lasting scientific importance: Can we learn to report these happenings objectively and with attention to the relevant facts? Will comparison of such happenings yield general knowledge defining the circumstances under which social change is favored or hindered?

CEREMONY PERFORMED IN CHAN KOM

TO SECURE RAIN FOR THE CORNFIELDS. THE SHAMAN KNEELS AT THE ALTAR; AT HIS LEFT AN ASSISTANT SPRINKLES THE ALTAR WITH THE CEREMONIAL BARK BEER.

It must be taken into account that we, as observers, are ourselves factors bringing about change. Mr. Villa comes to regard his school and its activities as a laboratory experiment that he has set going. Whenever one of the scientists working on one or another of the Carnegie Institution projects visits Chan Kom he is likely to introduce some idea interesting to the people. Dr. Shattuck gave a talk on microbes; the people understood these to be little ants gnawing their vitals; for a few days every one felt them biting away inside and the shamans did a thriving business in exorcism. Dr. Soundground's explanation of the function of vitamins in the dietary made the tomato fashionable for a short time; but a year later the vitamins had become merely part of the local folklore—three little beings, a triad as mystical as the Trinity, one making bones, one flesh and one blood.

As we become increasingly interested in the contemporary life of these village people and the changes going on in this life, we come more and more to look upon their world through their own eyes. It is then plain how different is the historical meaning of what they do from its actual present meaning. To the student of archeology, who has seen in murals on ancient Maya temples at Chichen Itza representations of the four priests known as Chacs holding a human being by the limbs that he may be slain in sacrifice, it is especially interesting to find the Chan Kom people designating by the same name four men who hold by the wings and legs the turkey about to be killed as an offering for the gods. But the villagers are oblivious of the historical origins of this custom, and it means no more and no less to them than does the act of crossing oneself, or any other piece of ritual in their mixed pagan and Christian religion.[3]

[3] But the Shaman-priest himself told us that "in the old days it was a human being, and not a turkey."

THE FOUR BOYS WHO IMPERSONATE FROGS,
CROAKING TO BRING RAIN, AT THE RAIN CEREMONY IN CHAN KOM.

As archeologists, we look upon these Mayas as the descendants of the builders of the temples, but they do not so look upon themselves. They have no sense of connection with the old cities, except that Coba has a vague prestige, a certain uncanniness; certain gods and mythical monsters dwell there, and shamans who have visited these ruins have there secured unusual powers. Both Chichen Itza and Coba are mentioned in ritual prayers, but the meaning of the words uttered is not always intelligible to the average listener.

Some of the interest the present-day Indians exhibit in the old ruins may be a recent development rather than an old survival. There is a contemporary folktale about a serpent, named Xkukican, who once lived at Chichen Itza and was wont to devour children—this may very well be a vestige from the old human sacrifice and the cult of the plumed serpent (Kukulcan). On the other hand, contemporary explanations as to the meaning of some of the old carvings at Chichen Itza, or stories that make use of the ancient Ball Court as a race track for folk heroes, do not necessarily involve any such survival, but may simply be the result of myth-making since the Conquest.

At any rate, to the present-day Maya, the builders of these great temples were of quite another race, no ancestors of theirs. They were the Itzaes, great people of supernatural powers who dwelt a long time ago. Some villagers confuse these Itzaes with still another race, a dwarf people, who had the magical knowledge that made possible the building of vast cities of stone. They knew the whistles that caused these stones to leap into place of their own accord. But through their carelessness, or impiety, this knowledge was lost and the dwarf people were all destroyed. This happened long ago, "before our grandfathers were here."

And to-day any vestige of the ancient Maya, having for the Maya of to-day nothing of its old meaning, is simply

uncanny, or downright dangerous. Fragments of obsidian knives are the sling stones of the gods who guard the cornfields, and clay idols are evil midgets that it is best to smash where they lie, lest they come alive at night and work harm to men. One ceremony, occasionally performed, takes place at a stone ruin of ancient days, and has for its purpose the propitiation of these pottery goblins.

Such concerns occupy only a small corner of the villagers' interests. In our studies we are seeking to look on life as they do, and to see things in the perspective and with the sense for relative importance which characterizes their own outlook. To know a culture is to know how its objects and its actions appear, not to anybody on the outside, but to the people who deal with the objects and perform the actions.

Toward this goal progress is made through intimate association with the people, the sort of sympathetic, yet detached consideration to which Mr. Villa has been devoting so many months. There seems to be no short cut to intimate acquaintance. Circumstances may be more or less favorable, but at the best much time is required. Nevertheless, one feels the need for some method of investigation that will give to this intimate exploration some degree of objectivity, that will result in materials of permanence and consultability. Here again we are fumbling for useful devices.

Following the suggestions of others we are especially attentive to revelations of attitude and view-point through the experience of particular individuals. These villagers are human beings with the same tendency to shame, pride and conceit that other people have, and they most reveal their culture when they let us see what it is they are characteristically proud of, or ashamed of. Spontaneous comment on current situations is illuminating, but it is fragmentary and fugitive. Longer connected statements of personal experience are harder to obtain, and when obtained are apt to be less spontaneous. Still, we have one autobiographic document of about ten thousand words from a man of this village, that puts a lot of content and added significance into the bare statements as to custom and attitude set down in other parts of our notebook.

For example, although we were aware in general terms of the importance of the marriage settlement in fixing the social position of the couple, it was not until we read this man's account of his own marriage, apologetically commenting on the small amount of property involved, that the real significance of the custom appeared. This autobiography also brings out very vividly, in terms of the life experiences of one man, the conflict between the younger more progressive element in Maya society and the authority of the shamans, who, in receiving rum and money in connection with certain traditional customs which they supervise, represent a conservative vested interest in the village life.

And we had little idea of the limits of the natural community to which local loyalties attach until we had this man's own account of how the local fatherland, including perhaps half a dozen villages and their satellite hamlets, was aroused to concerted military action by disorders incident to the recent revolution. Then the distinction between "our people" and all outsiders was made perfectly plain in the roster of pueblos that fought together. It is interesting to the student of history, incidentally, to note that this little world of patriotic attachment to-day corresponds very closely with one of the several Indian principalities, or *cacicazgos*, into which the old Maya confederacy broke up just before the coming of the Spaniards.

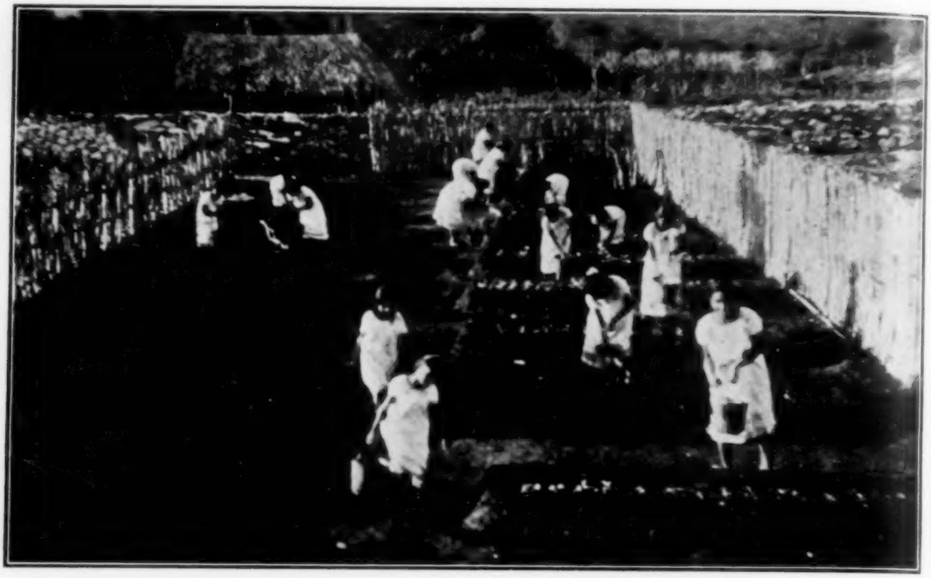
THE MAN IMPERSONATING THE GREAT RAIN-GOD (KONKU CHAC) RECEIVES HIS CUTLASS AND CALABASH, WITH WHICH HE IS TO MIMIC THE LIGHTNING AND THE RAIN.

The scientific usefulness of these methods of inquiry will be better tested when we shall have tried them in some of the other communities we hope to study. During 1932 we plan to carry on studies in one or more communities in or near the capital city of Merida. Here again there is a problem in wisely selecting the samples to be studied; it is apparent that there are communities of different sorts: for example, colonies of city-wise shop-workers, as contrasted with settlements on the outskirts of the city of Indians only recently come from the country villages but finding their employment in the city itself. We hope to find in such communities other aspects of the process of transition observable in Chan Kom.

Looking in the other direction from Chan Kom, southward and toward the more primitive rather than northward and toward the more civilized, we find in the territory of Quintana Roo a group of villages in which Mr. Villa is to begin work during the coming year. These are villages of Mayas who turned their backs on the towns and the ways of white people after the race war that took place in Yucatan in the middle of the last century, and who still remain relatively isolated from the white man's civilization. Here it is probable that we shall find much the same customs as in Chan Kom, but a very different social setting.

A cursory impression suggests that differences in customs are minor: the women wear necklaces of Guatemalan coins instead of the gold chains of Yucatan; the dead are buried not in Christian cemeteries but in the streets or under the floors of houses; the patriarchal extended family organization is perhaps better developed than in Yucatan; and in the mixed-Christian religion the cult of the cross probably plays a more important rôle.

But in outlook on life these Mayas of Quintana Roo are probably very differ-



THE SCHOOL GARDENS AT CHAN KOM,
PREPARED ACCORDING TO MODERN HORTICULTURAL METHODS.

ent from those of our first village of Chan Kom. Contact with the outside world is not through the teacher and the tourist, but through the traveling merchant and the gatherer of chicle. This fact, and the traditions of hostility toward the Mexicans, maintain in them an aloof and independent attitude. Organization is tribal. The several villages are united in a military-religious federation under the symbol and control of a "talking cross," an oracle enshrined in a little interior village, that delivers, mysteriously, omens and warnings that are carried to all the subsidiary villages by men drawn in rotation from each hamlet to do vigil at the seat of priestly government.

In this part of the Maya world, one imagines, change is thought of as undesirable, and the prestige of the shaman is not seriously challenged. Yet these communities are changing, too, probably not as rapidly as is Chan Kom, and in response to different, and—from the point of view of the whole process—earlier influences, such as the first school and the gatherer of chicle.

This statement as to our purpose, and as to some of our perplexities, may be brought to an end by a summary of what we may reasonably hope to obtain through these projected studies.

There will result a body of information as to the customs of the Maya in certain parts of the Yucatan peninsula. This information will have whatever intrinsic interest such ethnological materials ever have. Some of it may have a direct practical value in enabling Mexican administrators, educators and reformers to deal more effectively with their problems.

Mr. Villa has come to understand the difficulties in the way of educating the simple villagers to whom he has been devoting the years of his youth. He was instructed to teach them reading and writing of Spanish by methods devised in the capital and sent down in printed instructions—a people who had nothing to read and little desire to do

so, and whose domestic language was Maya, not Spanish. This he accomplished, but he soon saw that for his successful pupils literacy was like the learning of a trained dog—diverting, but unimportant. In fact, in making the census enumeration this teacher set down as able to read and write Spanish a score of persons who were in another column recorded as unable to speak that language. The educational policy of Mexico has been remade in response to suggestions derived from an acquaintance with the interests and customs of that country's backward folk; and, generally speaking, the success of reform and control increases with the knowledge of the people.

Some of this information as to Maya customs may be of interest to the historian of American Indian civilization, especially as it may throw light on the life of ancient Maya. But we must be cautious in drawing conclusions as to ancient practises from contemporary customs. Maya culture has undergone very great changes since the Conquest. The old calendar, writing and quasi-philosophical religion were perhaps never complete possessions of the common Indian; and therefore it is no wonder that the Spaniards easily destroyed all this. But simpler cultural elements, originally probably widely present, have likewise disappeared. The ancient Mayas ate dogs, for example, but the Maya Indians of my acquaintance regard the idea with the same distaste with which most of us regard it.

Nevertheless, some light on ancient Maya life may be expected to come from these investigations, especially in so far as attention is paid to the less civilized groups and to the older men. An example of how such light may be thrown may be given. In some of the old Maya manuscripts the name of a certain deity occurs without explanation. The same

TO DRIVE OUT DISEASE-BRINGING WINDS

FROM THE BODY OF AN AFFLICTED GIRL, THE SHAMAN STROKES HER WITH CERTAIN LEAVES, MEANWHILE RECITING PRAYERS TO THE SAINTS AND TO THE PAGAN GODS.

A CEREMONY FOR THE GODS WHO GUARD THE CORNFIELDS, PERFORMED TO RELIEVE THE OWNER'S SICKNESS. THE SHAMAN CONSULTS HIS CRYSTAL TO DIVINE THE WILL OF THE GODS.

name occurs in present-day Maya prayers in a context explaining that the god was a patron of the bees and himself thought of as a giant bee. This makes it at least possible that the ancient god of this name was of the same character.

Where outside factors hold behavior relatively constant, as for example the time and labor used in growing corn and burning lime, information derived from present-day life may be directly transferable. Earl Morris, Carnegie Institution archeologist, has made good use of this material, investigating the time and labor required in burning lime and cutting wood, as practised by the contemporary Maya, in order to throw light on the man-power necessary to build some of the stone structures at Chichen Itza.

We have computed the amount of land necessary to support the contemporary Maya population of the village we are studying and have reached an estimate of six hectares of cultivated land per year per inhabitant. As land is cultivated there on an average of only two years out of seven the total amount of tillable land which must always be available is about twenty-one hectares per inhabitant. But before these figures can be used as the basis for an estimate as to the population that could be supported on the peninsula in ancient days it will be necessary not only to determine that this is a fair sample for the entire region, but also to take into account changes that have taken place in the economic life of the inhabitants.

The introduction of iron tools is one such factor, but others even harder to estimate are changes in the dietary, notably the introduction of poultry and some beef and pork, and also the introduction of factory-made textiles and other goods which must be paid for out of excess corn produced. It may be that in the old days a man had to raise twice as much corn as he and his family consumed, as is the case now, but we would have to know this before the fig-

ures could be used to draw conclusions as to the maximum population the peninsula would support under ancient conditions.

Perhaps we shall get more help from the students of the ancient Mayas than we are able to give them. Had we not known, for example, of the importance of the idea of the four directions in ancient Maya thinking, it might not have occurred to us to note just how many piles of stones, each surmounted by a cross, are placed around Maya villages. Once we had investigated, and there had proved to be four—whether there be four or fourteen roads leading into the village—it was easy to push the inquiry farther and determine that the contemporary village in the region was oriented with respect to the four corners of the world, each still under the protection of a particular god.

But more important than any amount of information, we may hope for some improvement of the methods of study of culture changes. If we can add anything to such methods, we shall have justified the expenditure. For then there will be something that can be taken away from this field and used in others; there will have been some sharpening of a tool or two with which to attack the problems of contemporary circumstance.

If the study of several communities along the range of civilization is carried out as planned, it should itself constitute a sort of case-history of the process of civilization. If the several communities are studied in such terms as to assure the student that the essential modifying factors have been taken account of, this series of related studies will furnish a background for further inquiries into special problems, as, for example, the growing function of money, or differences in the age-groups and personality types from which leaders are drawn, in communities at varying stages of culture.

This list of possibilities and aspirations may be extended to include the hope that in this attempt to develop methods for the study of culture in Yucatan, our developing interest and skill may go along with that of the people of Yucatan themselves. If some of them come to study the contemporary people, as they are already studying the ancient people of Chichen Itza and Uxmal, the value of our own studies will become a permanent value.

There is a great need for trained students of contemporary cultures, and those who are already on the ground, speak the language and are stimulated by the practical problems that concern them directly have in these respects superior qualifications for such work, as compared with foreigners. We hope such students may appear in Yucatan. Science is not so much going some place to get facts, as it is continuing and developing ways of dealing with experience. The important task is to get these ways going in the new places, and to improve them everywhere.

EARLY HISTORY OF PETROLEUM IN NORTH AMERICA

By Professor CAREY CRONEIS

WALKER MUSEUM, UNIVERSITY OF CHICAGO

WHEN a country, a family, a science or even an industry is "on the make," there is no time and little inclination for writing its history. But when an empire finds "its place in the sun," when a dynasty is finally established, when a science is widely taught and extensively employed, or when an industry becomes fundamental, then comes a "breathing spell," in which their achievements begin to be recorded. Only then are the details of the early struggles which made them possible exhumed from the contemporary, and often contradictory, accounts. Indeed, the very appearance of annals is to the cynic a tacit confession of the early stages of desuetude.

That the oil and gas industry, and petroleum geology as well, are not now on the crest of the wave, no one will deny. But that they are already destined to go the way of the Roman Empire or the Medici family, only a few of the most pessimistic would affirm. Nevertheless, the industry and the profession have now reached that stage of robust maturity and (just now, enforced) leisure in which they are interested in their own early beginnings. This is evidenced by the fact that in the last few years a number of geologists, engineers and even captains of industry have been gathering together and publishing, chiefly in technical journals, some of the pertinent data regarding the early history of petroleum and petroleum engineering in North America.

Their accounts have dispelled, from the minds of the experts, many of the misconceptions and not a little of the misinformation that has become so inseparably linked with the rapid growth of any industry or profession. But additional somewhat iconoclastic data regarding the first years of commercial oil production are contained in the newspaper accounts of that period, and in a number of essentially contemporaneous books. Inasmuch as some of these volumes, as well as other relevant facts, are now unavailable, even to the average technologist, and because the layman has never really been informed of the glamorous pioneer days of one of the greatest of the modern industries, there is summarized here a few of the less well-known data concerning that early period. But before plunging into these historical accounts let us briefly review a few of the steps leading to the modern development of this megalomaniac industry.

In our present-day industrialism, oil and gas are regarded as indispensable, yet less than 75 years ago not one drop of oil nor a cubic foot of gas was produced in the modern sense of the word, though a few "gas springs" were known, and a little oil was skimmed from seeps for medicinal purposes. The pioneer wells of the late fifties of the past century were essentially hand drilled; those of to-day are put down by the most elaborate machinery. The early wells cost a few hundred dollars; many of those drilled to-day cost more than one hundred thousand, and a few have required a quarter of a million dollars for their completion. "Colonel" Drake's discovery well of 1859 yielded 25 barrels of oil a day from a depth of less than 70 feet; some of the modern

producers have a potential capacity of more than 200,000 barrels a day, and some have tapped the oil sands at depths of more than a mile and three quarters. The total world production of oil seventy years ago was only a few thousand barrels, but, owing to the increasingly feverish rate of production, "Old Mother Earth" has now yielded approximately twenty billion barrels of the liquid gold, of which about 65 per cent. was produced in the United States. In fact, at the time of peak production (August, 1929) this country alone was producing oil at the rate of more than a billion barrels a year.

A billion barrels of oil a year is an almost inconceivable amount of petroleum, but even this does not represent the total potential production of our prolific fields. Man in his avidity has overdrilled most of the known productive areas until at many places the derricks at a casual glance seem to be in lock-step. As a consequence, far more wells have been drilled than actually were necessary for the optimum recovery of the oil. Thus it happens that the statement, "A dollar and a half has been spent for every dollar's worth of petroleum produced," is not far from right. As a further consequence of over-drilling in some fields, several states have found it necessary to prorate the production of each of its wells. This proration is especially effective in California, Oklahoma and Texas, the great oil triumvirate, where production is now limited to about one half capacity.

In spite of our seeming deluge of oil, and the relatively recent price of a few cents a barrel in the East Texas field, many a disillusioned prospector will tell you that "oil and gas, like gold, are where you find them." So they are! But through the intelligence of man in general and of engineers and geologists in particular, and, I must confess,

"COLONEL" EDWIN LAURENTINE DRAKE, ABOUT 1865.
FROM AN OLD ENGRAVING.

through sad experience as well, we have learned that they are invariably found in "certain places."

Through the efforts of Dr. I. C. White, for many years state geologist of West Virginia, it became apparent (by 1885) that the most prominent of these "certain places" are localities in which the rocks are up-folded into the structural condition known to the geologist as an anticline. In other words, disregarding entirely the highly controversial subjects of the origin and migration of oil and gas, these substances generally accumulate in porous beds which are bowed upward. Once this principle was established, scientific drilling was limited to the relatively small and fairly easily determined anticlinal areas; and thus the percentage of dry holes greatly decreased.

The claims of Thomas Oldham, T. S. Hunt, H. D. Rogers, E. B. Andrews, Sir William Logan, Alexander Winchell and others for priority in connection with this anticlinal theory often have been aired. But, as J. V. Howell says, "It remained . . . for I. C. White to put in clear and concise form, with ample

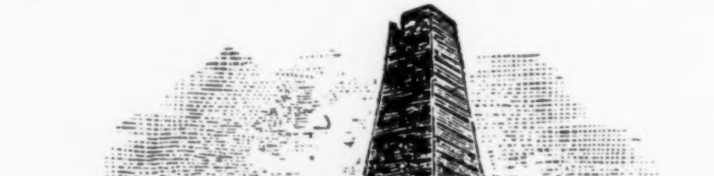
supporting evidence, the theory as it is now known, and furthermore to apply it widely and with undoubted success." White himself has generously acknowledged that it was Mr. William A. Earseman, of the Forest Oil Company (later a part of the Standard Oil Company), who, although not a geologist, pointed out to him that a number of gas wells were located near points on maps where the Geological Survey of Pennsylvania had drawn anticlinal axes.

But nearly twenty years before White became interested in anticlinal control, a Canadian public land surveyor, Henry West, fully comprehended the practical value of this principle. This is conclusively indicated by a number of facts. On the title-page of his "Geology, Oil Fields, and Minerals of Canada," dated May 1, 1865, he states that the accompanying map shows "each lot, concession, and *oil bearing anticlinal.*" In his preface he says further concerning the map that:

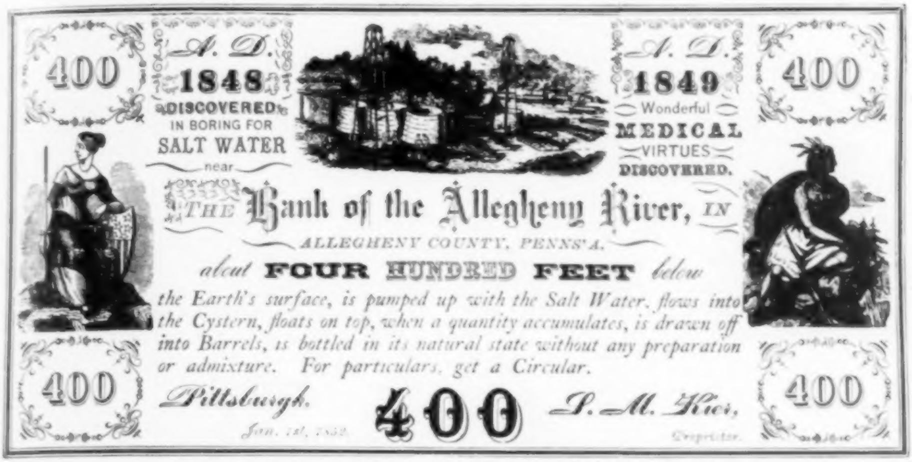
> The different formations within that area are distinguished upon it by colours; and the main anticlinal axis in which (and its subordinates) petroleum may be expected to be found, are also marked as bands, from the east, to where they make their exit in the western extremity of the Province, at the upper end of Lake Erie, etc.

Later, he continues with some very definite statements. The italics are his:

> Scientific reasoning and inferences, which subsequent practical experiments have so far fully confirmed, has demonstrated that *it is at, along, or near the crown of these anticlinals*, in hydrocarbonaceous bearing formations that liquid *petroleum may be expected to be found.*
>
> Some of the springs in Western Canada appear to be on the line of the great anticlinal as before indicated, and others are, no doubt, either on, or connected with subordinate undu-



"DRAKE'S FOLLEY"—THE DISCOVERY WELL.
FROM AN OLD ENGRAVING.



THE LABEL THAT STARTED AN INDUSTRY
FACSIMILE OF THE ORIGINAL.

lations; for, the oil being lighter than water, and permeating with it the strata, naturally rises to the highest part, or crown of the different anticlinals, where it is confined, and from whence it escapes into the overlying deposits, or to the surface by natural rents, cracks, fissures, or borings. By the sinking of wells, and the aid of artificial borings, into the underlying oil bearing rocks below, and the recently discovered improved modes of refining it, as well as the various purposes of life to which its uses have been and can be applied, has been the means of greatly increasing its supply and augmenting its demand. Rock oil has therefore created quite a mercantile revolution in the article of light alone; and caused an almost unparalleled new branch of manual, mechanical, and speculative industry to spring up within a very short period.

It therefore becomes a matter of the greatest importance to enquire, and if possible, determine where these anticlinals and their subordinates are located in oil bearing formations.

West gives not a single reference, so that it is impossible to ascertain whether or not these ideas are original with him. It is just possible that he borrowed some of them from Hunt, whose somewhat similar views had appeared in print four years previously. But, at any event, no one at this early date had had so clear a conception of the importance of structure in the accumulation of oil and gas, nor of the method of outlining such structures by means of drilling data. This is well demonstrated by the following paragraph, in which the italics are West's:

I shall therefore conclude this part of my subject with the advice that, having pointed out the formations and localities in which natural oil is known to exist, and may be expected to be found; and seeing also that reason and experience have confirmed the fact, *that, it is at or along the crown of these anticlinals that petroleum centers or collects; we must, in order to be successful, look for these anticlinals in oil-bearing formations. They are sometimes (where not covered over by too much drift) marked by slight elevations on the surface; but it is only from a minute examination and measurement of the angular inclinations of the sub-strata that the precise locality of the anticlinals can be definitely determined. This is an easy process when exposures occur, or facts noted, in deep borings. For if, from the same surface level, several borings are made in an oil-bearing neighborhood in various given directions, and the several depths of the same strata noted, it would be easy to determine the inclination of the underlying strata, and where the crowns of the anticlinals are located, and may be found, and where borings may reasonably be expected to be successful in the production of liquid petroleum.*

The revival of old depleted oil wells is another petroleum practise which is

GEORGE H. BISSELL ABOUT 1870
FROM AN OLD WOODBURYTYPE

generally considered to be a recent engineering triumph. Indeed, A. Beeby Thompson, in 1925, said, "Previous to the year 1905 the Baku oil fields of Russia offered a very favorable field for air lifts. . . . In 1899 the first experiments with an air-lift were made under the supervision of the author."

A much earlier instance of the revival of old wells, and the use of a primitive, but apparently effective sort of air-lift is recorded in the following Pennsylvania newspaper account of 1865, reported in "Derrick and Drill." The italics are mine.

The large flowing-wells have generally stopped after twenty-five or thirty months' flow. Some few have continued, with diminished volume, over three years. The pumping-wells have averaged about the same duration. In 1863, and until the latter part of 1864, comparatively few new wells were sunk. During this period many wells gave out, and many were abandoned. It was never ascertained, until within the past eight months, that wells which had ceased to produce oil could be made to resume their yield. This fact is now established. *A great many wells that were considered exhausted have been resuscitated, and are now yielding very considerable quantities of oil.* Among the noted instances are the Empire well, on the McElhenny farm, *now flowing, under the pressure of an air-pump, a hundred barrels per day;* the Buckeye well on the same farm; the old Sherman well, on the Sherman flats; and the old Phillips well, on that farm, has spontaneously resumed its flow, after occasional interruptions, since October, 1861. Wells are caused to flow spontaneously by the pressure of naphtha gas within the earth being greater than the pressure of the atmosphere. When this greater pressure is reduced by exhaustion to an equilibrium with the atmospheric pressure, the flow ceases until artificial pressure is applied, or until a fresh accumulation of the gas causes a resumption of the flow. . . .

It may be safely said, then, that it is, up to this time, not the exhaustion of the oil, but the exhaustion of the gas which elevates the oil, that has produced an embarrassment to oil mining which threatened at one time to hazard its success, but which is now obviated by the application of new and efficient inventions.

The famous Professor Henry D. Rogers, himself, may have written this account. At any event, in 1865, the same year the quotation was written, he gave a paper before the Philosophical Society of Glasgow, in which at one point he used essentially the same words as those of the last paragraph above to propound this modern idea.

The place of "Colonel" Edwin Laurentine Drake (1819–1880) in the annals of petroleum is well established, but in recent years only a few writers have cared to give any but the legendary story about him. Moreover, the importance of George H. Bissell and the rôle of Samuel M. Kier in the early history of the industry are now essentially forgotten. The interrelationship of the work of these three men makes an interesting story. In part, it can be reconstructed from newspaper accounts. A writer in the *Meadville Republican* of March, 1865, signing himself "W. H.,"

sent the following letter from Alleghany College:

Having occasion recently to look into the origin of refined petroleum, and its application as an illuminator, I was surprised to find that the man who was unquestionably the first to apply refined petroleum to illuminating purposes is entirely overlooked in the published histories. This is the case in Appleton's Cyclopedia, which, however excellent in other respects, needs some amendation in this. For the sake, therefore, of historical justice, and lest it should happen on this (as it has happened with some previous valuable discoveries) that due credit should not be awarded to the proper person, I propose to make a brief statement of facts in behalf of a very worthy but modest man, who is certainly entitled to the honor of having first introduced this almost incomparable illuminator to the public. I refer to Mr. Samuel M. Kier, of the city of Pittsburgh.

The facts as stated in Appleton are substantially these: That the success attending the manufacture of Coal-oil, and the identity of the crude coal-oil with the natural petroleum, suggested the idea of applying to the natural oil the same methods of purification invented for the artificial; that the first movement of this kind was made by Eveleth & Bissell, of New York, in 1854, who tested some oil from Oil Creek, the result of which was satisfactory. After this no progress was made for some time. . . .

The statements I have to make in favor of Mr. Kier's priority are these, abridged from valuable data in my possession. About the year 1849, Mr. Kier discovered oil coming up from one of his salt-wells near Tarentum, on the Allegheny River.[1] After a time it accumulated in the receiving tank to such an extent as to become troublesome; and not knowing what use to make of it, he let it run away. Oil was discovered about the same time coming up from another salt-well (Mr. Peterson's) in the same neighborhood. About six months after the discovery, Mr. Kier conceived the idea of putting it up as a medicine, and to prevent competition, purchased also the oil from Mr. Peterson's well for five years. Some of the oil was then disposed of, but Mr. K. found in the course of a few months that he could not thus use all the oil the wells were producing, and did not know what to do with the surplus. He sent a portion of it to Philadelphia, to Professor Booth, to have it analyzed, in hopes of finding some other use for it. When Mr. Kier went to see Mr. Booth, the professor informed him that he found the largest portion of it naphtha, which, he thought, would be useful in the gutta percha manufacture as a solvent. Mr. K. went to New York, had it tested, found it would not answer, and reported accordingly to Professor Booth. The professor then told him that if he could get a suitable lamp constructed to burn it, it would make a splendid illuminating oil. He also gave him instructions how to distill or refine it. Mr. K. went home and immediately got to work, put up a little refinery, and informed the mechanics what kind of lamp he wanted. Soon two men came in on the same evening, each having a lamp in his hand. They lighted them, and such was the effect, that each one claimed the superiority for his own manufacture, and they commenced quarreling over the merits of the respective lamps. Mr. K. reconciled them by concealing the excellencies of both, and suggested a partnership. They opened a lamp store on Wood Street, Pittsburgh, Mr. K. furnishing the oil. They proved, however, to be "crooked sticks," who soon quarreled again, and first one left and then the other, leaving the whole business on Mr. K.'s hands. Such was the demand for the oil now, that he could not get enough from his wells. But he thus used all he could obtain from his own and other salt-works for about five years, from 1850 to 1855. The year before this latter date is the one named in Appleton as the time when Eveleth & Bissell made their experiment with oil from Oil Creek. Mr. Bissell gets the credit of first conceiving the idea of boring for oil. He, and perhaps other parties interested, sent out Mr. Drake, who sunk the first well on Oil Creek. This was, I think, in 1859. Before commencing his operations, Mr. Drake went to Mr. Kier's wells on the Alleghany, examined them, and hired a blacksmith who was then working for Mr. Kier to go and bore for him. The result is well known. Mr. Drake struck oil at about seventy feet, from which dates the great oil excitement of the day. But it may not be known that Mr. Kier bought the first oil that came from Mr. Drake's well, and refined it at his refinery. From these facts it would seem that Mr. Kier, of our own good commonwealth, prompted and assisted by Professor Booth, also of our State, refined and used refined petroleum, as an illuminator, for from four to five years before the first well was sunk on Oil Creek. This many of the purchasers of Kier's "carbon oil" in Pittsburgh and elsewhere can testify. Before oil was obtained by boring on Oil Creek, the writer himself brought here, from Mr. Kier's

[1] Other documents show that the Kiers, father and son, had been troubled by oil in their salt wells for "many years" prior to 1849.

establishment in Pittsburgh, the first "carbon oil" and lamp that ever came to the place.

But in addition to being a pioneer refiner as well as the man who supplied the mechanic to bore Drake's well, Mr. Kier was indirectly responsible for Bissell's very idea of *drilling* for petroleum. This results from the fact that the "medicinal oil," which Kier put on the market in 1849 at fifty cents a bottle, carried an extraordinary label which was to play an important rôle in the lives of Bissell and Drake. But before going further into this story it is necessary to outline some of the early activities of Mr. Bissell, who, although now essentially forgotten, was without doubt the guiding spirit in the embryonic days of the petroleum industry.

George H. Bissell (1821–1884) was born in Hanover, New Hampshire, was graduated from Dartmouth College in 1845, and was for a short time professor of Greek and Latin at Norwich College. After newspaper service in Cuba and later at New Orleans, he became the superintendent of public schools at that city. In 1853 impaired health forced him to return north, where he formed a law partnership with J. G. Eveleth in New York City.

Calling on his old tutor, Professor Crosby, at the latter's office at Dartmouth, he saw there a bottle of petroleum from Oil Creek, Pennsylvania. This oil had been brought to Hanover by another Dartmouth graduate, Dr. F. B. Brewer, who, having used it successfully in his practise, had submitted a sample for analysis. Mr. Bissell's active mind at once visioned the possibilities in this product, and, with Mr. Eveleth, he immediately purchased for $5,000 what were thought to be the chief oil-lands of Pennsylvania. Then in 1854 these two men organized "The Pennsylvania Rock Oil Company," the forerunner of all the modern oil corporations. Thus, modestly, began a present $4,000,000,000 a year industry!

The company attempted, without much success, to develop their lands by means of trenching for the oil. Not discouraged by the small amount of petroleum obtained in this fashion, Bissell and Eveleth employed Professor B. Silliman, Jr., of Yale, to analyze their product. Professor Silliman's report, published in 1855, attracted considerable attention in the East, and led to the reorganization of the company with Silliman as president.

Some idea of the difficulties attending the early stages of organization may be gained from a letter written from New York on November 6, 1854, to the same Dr. Brewer who brought the first sample of oil to Dartmouth. The letter follows:

Dear Sir: We have had to encounter many obstacles in the way of organizing our joint-stock company, and shall be unable to get out our papers at the time originally proposed.

Mr. Eveleth will go on at the earliest possible period and will then be prepared to arrange everything to our mutual satisfaction. I do not think, however, that it will be possible for Mr. Eveleth to arrive in Titusville before the 18th or 20th inst.

We have obtained our stock-books, certificates of stock, signs, etc., etc., and have done everything to insure success when we fairly get under way. We have forwarded several gallons of the oil to Mr. Atwood of Boston, an eminent chemist, and his report of the qualities of the oil and the uses to which it may be applied are very favorable. Professor Silliman of Yale College is giving it a thorough analysis, and he informs us that so far as he has yet tested it, he is of opinion that it contains a large proportion of benzole and naphtha, and that it will be found more valuable for purposes of application to the arts than as a medicinal, burning or lubricating fluid.

Our expense of a thorough analysis will be very heavy; but we think the money will be well spent. We send you a proof-sheet of our certificate of stock. The book will be printed of course on bank-note paper.

Let us hear from you at your earliest convenience, and believe us,

Very truly yours,
EVELETH & BISSELL

There is no doubt that Silliman's report, although certainly not prophetic, really determined the economic value of petroleum, since it proved that for many purposes it was superior to coal oil. His exhaustive analysis, which cost $1,200, was paid for entirely by Bissell and Eveleth. Inasmuch as they were only moderately wealthy men, their faith in the future of petroleum, in that earlier period of depression, must have been very great.

The value of their product now being established, their only difficulty was in enlarging the supply. But this, indeed, seemed impossible, for more elaborate trenching had failed to increase their yield. It was at this time that Mr. Bissell again showed himself to be a real pioneer by arriving at an idea. As J. T. Henry, an essentially contemporary writer, has said:

> It was the idea of obtaining Petroleum by means of artesian wells. It was a simple thought, but significant—a thought which, as Professor Silliman remarked, was the one of all others most naturally suggested by the various phenomena that had attended the discoveries of Petroleum in the saline of the Muskingum and Kanawha, the first idea that should have been suggested to a mind cognizant of all these circumstances; and yet, though himself editor-in-chief of the periodical[2] in which the circumstances were described, he very candidly confessed, that throughout the five months he was prosecuting the analysis, the thought of artesian boring never once occurred to him. And yet of all in any way connected with these first transactions, he was the only one of whom we had a perfectly reasonable right to expect such an idea; but Professor Silliman's interest in the matter terminated with the conclusion of his elaborate analysis, for though he perfectly comprehended its value, he never expected to see it obtained in any great quantity, and the two hundred shares of stock he held were given him in order to make him president of the company, and thus secure the prestige of a name renowned in science.

According to contemporary accounts, which, of course, may be apocryphal, Mr. Bissell arrived at this idea of drilling for oil in a peculiar fashion—and here Mr. Kier again enters the story. On a hot day during the summer of 1856, Mr. Bissell sought the shade of a Broadway drugstore awning. In the store window he noticed a remarkable show-bill lying beside a bottle of Kier's Petroleum.

> His attention was arrested by the singularity of displaying a four-hundred-dollar bank-note in such a place; but a closer look disclosed to him the fact that it was only an advertisement of a substance in which he was deeply interested. For a moment he scanned it, scrutinizing the derricks and remarking the depth from which the oil was drawn, till instantly, like an inspiration it flashed upon him, that this was the way their lands must be developed—by artesian wells.
>
> The idea was simple—at first it may also seem to have been self-evident, but reflect that the mind which grasped it must also have taken in a better conception of the philosophy of the existence of Petroleum than had any other mind before. When Mr. Bissell disclosed his theory to his partner that gentleman embraced with enthusiasm.

But legal difficulties in connection with the lease, which is a story in itself, and various other delays found little accomplished by early in 1858. At this time Drake at last comes into the picture. His true position is shown by an account written at Titusville by one who knew him.

> Mr. Townsend, then President of the Company, in lieu of Professor Silliman resigned, employed Mr. E. L. Drake, whom, in the darker days of its prospects, he had cajoled into purchasing two hundred dollars' worth of his own stock for the ostensible purpose of going to Titusville, to rectify the oversight mentioned in the lease, though the real object was not less to have him inspect the locality with a view of what followed, while it might be done at the expense of the Company. . . .
>
> Mr. Drake, though an intelligent gentleman, was the last one to choose for the performance of legal business, as no occupation of his life had prepared him for such duty; besides in order to give a pompous turn to the transaction in the eyes of the backwoodsmen, the legal documents, together with several letters

[2] *American Journal of Science.*

were mailed to "Colonel E. L. Drake, care of Brewer, Watson and Company," before ever the man left New Haven.

The title was the pure invention of Mr. Townsend who generously acknowledges his *pius fraudum*, and in the oil region and elsewhere, he has ever since been known as Colonel Drake. . . .

Meanwhile the Pennsylvania Rock Oil Company was having still other difficulties, and thus on the 23rd of March, 1858, there was formed another association designated as "The Seneca Oil Company."

The basis of their association was the lease. Mr. Drake appeared as the principal stockholder; but no stock was ever issued. It was in effect only a partnership, the members of which sought protection against each other under the laws for joint-stock companies. From the little influence he possessed in the management of their affairs, it is evident that Drake could have furnished but little of the capital. He was not in a situation to do so. For eight or ten years previous he had been a conductor on the New York and New Haven railroad, at a salary of seventy-five dollars per month, and the little he had been able to save from such a pittance had been swept away by an unlucky investment the year before.

Drake, engaged at a salary of $1,000 a year, arrived in Titusville with his family on about May 1, 1858. But for various reasons the well was not started until the middle of June, 1859. And then after many delays occasioned by the caving of surface material, Drake, about in mid-August, tried the experiment of driving an iron tube through the sands and clay to solid rock. This procedure solved the problem, and was Drake's only real contribution to petroleum technology.

On Saturday, August 28, 1859, the drill dropped into a 6-inch crevice, making the total depth of the well 69½ feet. Withdrawing the tools, Mr. Kier's former driller, William Smith, went home, intending to resume operations on the following Monday. But in examining the well on Sunday, "Uncle Billy," as he was called, saw a dark fluid in the hole. Plugging the end of a tin water spout he let it down with a string. When he drew out the spout it was full of oil! This was the humble prototype of the great modern oil wells.

The pump was at once adjusted, and the well commenced producing at the rate of about twenty-five barrels a day. The news spread like lightning. The village was wild with excitement; the country people round came pouring down to see the wonderful well.

Here again Mr. Bissell (as well as one of his partners, Mr. Jonathan Watson) showed his keen judgment; and Mr. Drake demonstrated his lack of understanding of the very product with which his name was to be inseparably linked.

Mr. Watson jumped on a horse and hurried straightway to secure a lease of the spring on the M'Clintock farm, near the mouth of the creek. Mr. Bissell, who had made arrangements to be informed of the result by telegraph, bought up all the Pennsylvania Rock Oil stock it was possible to get hold of, even securing much of that owned in New Haven, and four days afterward was at the well. His views of the matter had ever been the broadest, as his transactions had been the boldest.

While others were seeking for surface indications before leasing, he rushed forward, and secured farm after farm down the creek and along the Alleghany, where there were no surface indications whatever. The result has proven the wisdom of his conclusions. Drake unfortunately took a narrower view of the matter. He pumped his well in the complacent conviction that he had tapped the mine! He was probably led into this supposition by what seemed to him the remarkable incident of having struck a crevice. No money was paid on most of the leases taken at first; a royalty of an eighth or a quarter only being reserved by the easy old farmers who owned the land, and without a cent he might have secured any quantity of territory. He was repeatedly advised to do so by shrewd men who were themselves laying the foundation of fabulous fortunes; but it was his fatal misfortune to disregard that advice. When several other wells had been struck, and his eyes were opened to his mistake, it was too late, the golden opportunity had fled.

But by 1863, Drake, by acting as an oil commission merchant, and the Titusville justice of peace, had gathered together a fortune of about $16,000.

With this sum he entered the brokerage business in New York. In a few months he had lost it all. He came ill from a neuralgic affection of the spine, and returned to Titusville essentially as a beggar. The kind-hearted citizens at once raised $4,200 for the relief of himself and family. Finally, in recognition of his services to the state, the Pennsylvania legislature in 1873 granted him and his wife a pension of $1,500 a year.

In contrast to Drake's sad end, Bissell grew in wealth and importance. In 1864, he represented the oil dealers of Pennsylvania, and the Petroleum Board of New York, at Washington, where he successfully argued against taxation of crude oil before the Ways and Means Committee. He later became president or director of a number of large concerns. To his death he continued to maintain a powerful and beneficial interest in the industry which he had done so much to found.

I close this historical note on the early days of oil and gas production with a quotation which appears to refer to the modern epoch:

> The oil companies are, in turn, passing through an ordeal which will test their soundness. One result may be that of wiping out a number of them; another may be that of increasing the list. Three years ago the nation felt the shock of a universal rise of prices. It is now staggering under the greater shock of a universal fall. At what moment the cloud may actually burst it is impossible to say, nor how soon the skies may become commercially serene.

But this is history, too! The quotation, like the present paper, was written in April—but the year was 1865. Truly there is nothing new under the sun!

The oil and gas industry, the petroleum engineers and even the world at large should take courage from this unwarranted dirge from out of the past.

RELATION OF EDUCATION TO THE SUCCESS OF EMINENT WOMEN

By BERTHA BEACH THARP
YONKERS, NEW YORK

In the past it was thought perfectly proper for an English-speaking woman to do housework, enjoy a garden and to indulge in the fine arts or to assist her husband in his work, but custom forbade her working outside of the home for wages. To-day, this customary way of looking at woman's work is gradually breaking down under social changes which can be traced to a movement stimulated by the doctrines and philosophies inspired by the French Revolution and given further impetus by the Industrial Revolution. Women are now enjoying greater freedom, socially, economically and politically, than they have in any other period of English history. As a result of this freedom, women are being permitted to enter practically any of the occupations or professions they desire.

Under modern conditions, women are no longer content with the routine duties of the home, as were their mothers and grandmothers, and are constantly in search of opportunities for broader development. Parents, too, are seeking information that will aid them in preparing their ambitious and capable daughters for a successful life. With this in mind, a statistical study pertaining to the education of eminent women was made with a view of finding what correlation, if any, exists between education and success.

In approaching the problem, the most practicable procedure was to analyze educational data pertaining to women who have achieved success in recent years. It was found that "Who's Who in America" offered the best source for the desired information; accordingly, one thousand women were selected at random from this publication for 1929, and data pertaining to their education were assembled.

The first step in the analysis of the data was the grouping of the women according to occupations or professions representing their major activities. This grouping indicated that the great majority of the eminent women were engaged in professional work, while only a small proportion had entered business or an occupation. The largest group, or about one third, were authors, while the second largest group, constituting about one fifth, were educators.

There is a fairly high correlation between education and the success gained by the women of this survey, judging from the fact that about 75 per cent. of them were credited with training in addition to that received in high school. About one half of the women attended a college or a university, while about one fourth received training in an academy, institute or normal school or had private training. In the case of 158 of the women, no reference was made to their education, except that they had been educated in the public schools. These findings indicate that the chances of gaining success were about twice as great for the women who had a college education as for those privately trained or educated in an academy, institute or a normal school.

The chances for women gaining success without college education were much more favorable at the beginning of this century, as is shown by the fact that 32.25 per cent. of the women listed in "Who's Who in America" for 1903

attended college or a university,[1] as compared with 51.5 per cent. of the one thousand women included in the 1929 publication. The difference between these percentages indicates an increasing correlation between education and success. This signifies that it will be more difficult for women of the future to win success without higher education, notwithstanding the fact that it is often contended that a generalization concerning the relationship of higher education to success is of little value, since achievement is dependent upon both nature and nurture.

Even though there is a difference of opinion as to the weight that should be given to formal training as a factor in the achievement of success, few would deny that the mind is more quickly orientated to the vast accumulation of human knowledge by means of a college experience. These same women might have become prominent through their precocity and ambition without formal training, yet it seems reasonable to believe that their talents would be brought to fruition more quickly and effectively by institutional training than if left entirely to their individual efforts. This is, of course, a proposition which does not admit of positive proof.

It is of interest to note that Professor Dexter concluded from his survey made in 1903 that the correlation between education and achievement of success was not as great for women as it was for men.[2] The lower correlation, as explained by Professor Dexter, might be the result of a lower standard of eminence for women than for men. But granting there is truth in this explanation, it is reasonable to believe that the standard of eminence for women will become greater, since higher education is becoming more prevalent among women. According to the following data taken from the "Biennial Survey of Education" the number of college women is increasing rapidly.[3]

TABLE I

	1910	1928	1930
Number of women enrolled in colleges and professional schools	104,701	356,137	
Number of baccalaureate degrees conferred upon women	7,420	37,153	
Number of graduate degrees conferred upon women	602	4,858	
Number of females in U. S.*	44,639,989		60,637,966

* United States Statistical Abstract, 1929 and 1930.

While the great increase in the number of college women in our country is chiefly the result of economic pressure, leisure and a popular desire for learning are influencing factors. In response to the wide demand for education among women, many state coeducational institutions of higher education have been established, and knowledge obtained by all classes of women has been increased far beyond that of any other age.

It will be of interest to young women who are weighing the value of an education to know that in less than thirty years the correlation between success and education has become greater in ten of the professions listed in this study. According to a comparison of data of this survey with those of a similar one made in 1904, there has been a notable increase in the proportion of women having a college education among the physicians, social workers and journalists, as is shown in Table II. There was,

1 "Who's Who in America," 1903, p. xix.

2 "A Study of Twentieth Century Success," *Popular Science Monthly*, lxi, May–October, 1902, p. 251.

3 U. S. Department of Interior, Bulletin No. 16, 1930, p. 698.

also, a substantial increase among the missionaries, authors, educators and scientific women. The increase in the proportion of college-trained women among the artists, actresses and musicians is significant, although smaller than for the other professions.

TABLE II
PROPORTION OF EMINENT WOMEN ATTENDING COLLEGE, 1904 AND 1929 SURVEYS[4]

Occupational and professional groups	Attended college (per cent.)		Increase in proportion
	1904	1929	
Authors	12.70	46.58	33.88
Artists	2.90	20.00	17.10
Educators	46.00	76.11	30.11
Journalists	18.50	60.46	41.96
Actresses	1.70	19.40	17.70
Musicians	2.30	19.73	17.43
Social workers	14.40	54.68	60.28
Physicians	33.33	100.00	66.66
Scientific women	41.00	70.27	29.27
Missionaries	58.50	72.72	34.20
Librarians	??	85.18	....
Lawyers	?	100.00	....

The relation between success and college training was greater in certain fields of activity than in others. There is an exact correlation in case of the lawyers and physicians; and since 76.11 per cent. of the educators attended college and 70.27 per cent. of the scientific women, 72.72 per cent. of the missionaries and 85.15 per cent. of the librarians received higher education, there is a fairly close correlation in these cases. The correlation between success and higher education for the artists, actresses and musicians is comparatively low, but the relation in case of the social workers, politicians and authors would indicate that the women without a college education had as many chances of gaining success as did those with college training.

The taking of a graduate degree does not appear to have increased the chances of success, since as many women gained eminence with only a baccalaureate degree as did with a graduate degree. Of the 412 women who earned college degrees, 198 received baccalaureate degrees, while 214 took degrees representing more than four years of study. The number earning graduate degrees was slightly less than 214, since it was not possible in a few cases to distinguish earned from honorary degrees. The data show that only a small percentage of the authors, artists and musicians were credited with postgraduate work, while about half of the educators and scientific women received credit for advanced work. About one fourth of the journalists and one third of the librarians earned graduate degrees.

Four of the high correlations between success and college preparation were accompanied by low percentages of marriage, as is shown in Table III. About 50 per cent. or less of the lawyers, physicians, educators and librarians were married, while 76 per cent. or over in each group attended college. Quite the reverse took place among the artists, actresses and musicians. Over 50 per cent. of the women of each of these groups were married, while less than 20 per cent. were college trained. The librarians showed the lowest correlation between marriage and college education. The difference in correlation was not particularly great for each of the following groups—authors, journalists, missionaries, politicians and social workers. These data support the theory that education discourages marriage.

Data were compiled to show the ages at which the women of this survey were graduated. Although it was not possible to ascertain the ages of the entire group, a sufficient number were found to give a fair idea. The ages of graduation for the sample group ranged from sixteen to fifty-one years. In the field of art, 70 per cent. of the degrees were

[4] Amanda Carolyn Northrop, "Successful Women of America," *Popular Science Monthly*, lxiv, 1903–1904, p. 237.

TABLE III
PER CENT. DISTRIBUTION OF EMINENT WOMEN WHO ATTENDED COLLEGE AND WHO MARRIED, 1929 DATA

Occupational and professional groups	Per cent. of women married	Per cent. of women who attended college
Physicians	38.00	100.00
Lawyers	50.00	100.00
Librarians	22.22	85.18
Educators	35.84	76.11
Missionaries	54.54	72.72
Scientific women	48.64	70.27
Miscellaneous	60.00	70.00
Journalists	55.81	60.46
Social workers	75.00	54.68
Politicians	68.75	50.00
Authors	59.90	46.58
Artists	51.00	20.00
Musicians	67.10	19.73
Actresses	64.17	19.40

received on or before the twenty-third year, while in the field of science 56 per cent. were earned within this age range. No degree in science was taken earlier than the eighteenth year, while several degrees in art were received before this age. These data show a tendency for the degree in science to be taken at a more mature age than the degree of art, which result may be explained in part by a few of the women taking two degrees. When this occurred, the bachelor of art degree was usually taken first and the bachelor of science second.

The ages at which the master's degree was earned ranged from twenty to fifty-one years. About one third of the women whose ages were given took this degree on or before the age of twenty-five, while the remainder took the degree after that age. In the majority of cases a period of two or more years intervened between the time of taking the undergraduate and the graduate degree. Doing graduate work at a more mature age might very well be a factor which added to the superior preparation of the eminent women. Professor Thorndike, of Columbia University, has expressed the view that we err in considering early learning as a law of nature and as being invariably superior.

Since 258, or about one fourth, of the women of this study spent some time abroad, it is evident that there is a correlation between success and travel. Professor Ellis concluded from his study of "British Genius" that travel played an important rôle in the achievement of success.[5] The present study shows that 61 per cent. of the artists and 44.73 per cent. of the musicians spent some time in foreign countries. Only 28.80 per cent. of the educators traveled abroad; the proportion of those traveling or studying in other countries varied among the remaining groups from 24.32 per cent. of the scientific women to as low as 4.76 per cent. of the physicians.

It will be of interest to those who differ in opinion concerning the value of training women receive in coeducational institutions and that received in women's colleges to learn that 70, or 13.59 per cent., of the 515 college women enrolled in colleges exclusively for women; 100, or 19.41 per cent., attended women's colleges and coeducational colleges, while the remaining 345, or about 67 per cent., received their training in coeducational institutions. This means that only a small percentage of the college women were educated in institutions where men instructors did not predominate.

The proportion of eminent women who attended five of the large private colleges for women has practically doubled since a similar study was made in 1904.[6] Data in Table IV show that 51, or 5.34 per cent., of the women of the 1904 study attended either Bryn Mawr, Vassar, Smith, Radcliffe or Wellesley as compared with 134, or 13.4 per cent., of those included in the 1929 sur-

[5] Havelock Ellis, "British Genius," *Popular Science Monthly*, lviii, 1900–1901, pp. 59–67.

[6] Amanda Carolyn Northrop, "Successful Women of America," *Popular Science Monthly*, lxiv, 1903–1904, p. 237.

TABLE IV
NUMBER AND PERCENTAGE OF EMINENT WOMEN ATTENDING SELECTED WOMEN'S COLLEGES, 1904 AND 1929 SURVEYS

Name of college	1904 Survey*		1929 Survey	
	Number attending	Per cent. attending	Number attending	Per cent. attending
Vassar	19	1.99	33	3.3
Wellesley	13	1.35	32	3.2
Smith	8	.83	31	3.1
Radcliffe	7	.73	19	1.9
Bryn Mawr	4	.41	19	1.9
Total†	51	5.34	134	13.4

* Amanda Carolyn Northrop, *op. cit.*, Vol. lxiv, p. 241.

† Total number in 1929 Survey, 1,000; total number in 1904 Survey, 954.

vey. This increase, however, must be attributed in part to the fact that the proportion of women attending both private and coeducational colleges increased greatly during the same period.

To throw additional light on the educational background of these eminent women, it was thought worth while to assemble data pertaining to the sororities and the honorary organizations to which these women were elected, since membership in these societies is in a measure indicative of the social inclinations and scholarship of the women. Of the college graduates 28, or 6.79 per cent., were members of professional organizations, and 79, or 19.17 per cent., were elected to honorary societies noted for high scholarship. The majority, or 71, of those elected to honorary organizations were members of Phi Beta Kappa.

GENERAL SUMMARY AND CONCLUSIONS

It is very probable that the general results of this study could have been reached by reasoning and observing, but it is believed that conclusions carry more weight when backed by statistical data.

The evidence developed in this study shows that the proportion of women attending college has increased considerably among the women of "Who's Who in America" since the early part of the present century. The analysis supports the view that women trained in colleges have greater chances of gaining prominence than do women trained in institutions of less than college rank; however, data show that there is a higher correlation between college training and success in certain fields of activity than in others. The conclusion is that a college education is of less importance to the artist, actress and the musician than it is to the women in the other groups. It appears from the study that travel was an important part in the lives of the artist, actress and musician, but played a less important rôle among the women in other fields of work. Contrary to what might be expected, the findings show that among the college graduates the chances for success were as great for those who did no graduate work as for those who pursued advanced courses; nevertheless, the correlation between graduate work and success was greater in a few professions than in the others.

There is support in the study for the view that education necessary for success in certain professions means, in a measure, a sacrifice of marriage.

In general, the study shows a trend for education to play an increasingly important rôle in the gaining of success by women, and leaves the impression that women of the future will find it more and more difficult to compete for a place among the eminently successful without a thorough college training as a background for their work.

THE USE OF THE EXPERIMENTAL METHOD IN THE STUDY OF HUMAN PARASITIC INFECTIONS

By Professor ERNEST CARROLL FAUST
TULANE UNIVERSITY SCHOOL OF MEDICINE

Introduction

The earliest studies on parasitic infections and the diseases which they produce were observational and analytical in character. As early as 2,300 years before the Christian era the Chinese recognized the three species of malaria plasmodia on the basis of the types of fever which they produced. They also observed that malarial fevers or ague were associated with "spleen cake" or enlargement of the spleen. Later the Greeks and Romans not only differentiated the three kinds of malarial infections by the febrile reactions which they produced, but also associated their occurrence with swamps. However, it was not until the middle of the nineteenth century A.D. that any one suggested the possible relationship of mosquitoes or other insects to the transmission of this disease. The Medina or Guinea worm, ***Dracunculus medinensis***, was well known in the days of Moses; he instructed the Children of Israel how to twist this "fiery serpent" of the wilderness out of their skin onto a rod or stick, but he had no idea that the infection was initiated in man by swallowing a crustacean animalcule, Cyclops, in raw drinking water.

The Egyptians of the sixteenth century B. C. probably recognized Ascaris, the hookworms and tapeworms; the Greeks referred to tapeworms and hydatid, and the Arabian physician, Avicenna, who lived during the tenth century of our era, wrote on tapeworms, Ascaris, hookworms and the pinworm or seatworm (***Enterobius vermicularis***) and methods of expelling these worms from the body. After the Middle Ages physicians and workers in the natural sciences began to discover and classify various worms, visible to the naked eye, commonly found in man and domestic animals. Because they employed only external characters of the worms for purposes of differentiation they confused flukes (trematodes) with leeches and failed to realize that tapeworms and bladder worms were separate phases of the same life cycles. With the advent of the microscope the internal anatomy of the larger parasites (the worms) was studied and tremendous numbers of these organisms were described. This led to the erection of a huge system of artificial classification which is to-day possibly the greatest "white elephant" in attempts to elucidate the life cycles of these organisms. While the speaker does not wish to belittle the careful descriptions of parasites made by investigators of the past century, and realizes that these studies have been the foundation for all subsequent serious biological work on the subject, it is certainly true that the morphologist and the systematist by their shortsightedness have frequently kept the doors closed to the bigger, more vital sphere of experimental inquiry into the realm of parasitic infections.

Among the earliest helminthologists to realize the value of experimentation were Kückenmeister, who in 1852 and 1854 demonstrated that bladder worms were larval stages of tapeworms, and Leuckart, who with Virchow in 1854 elucidated

the life cycle of the trichina worm (*Trichinella spiralis*). Later (in 1882) Leuckart experimentally proved the relationship of the several stages in the life cycle of the sheep liver fluke (*Fasciola hepatica*), and in the same year demonstrated the successive stages in the development of the diminutive intestinal nematode parasite of man, *Strongyloides stercoralis*. Meanwhile, Fedschenko (1869) had incriminated Cyclops in the transmission of the Medina worm, and Patrick Manson (1878–1879) had shown that a culicine mosquito was involved in the transmission of Bancroft's filarial infection. With this latter discovery the modern epoch in experimental investigation may be said to have gotten under way, for it was due to this discovery that Manson conceived the idea of the mosquito transmission of malaria, which was successfully demonstrated by Ronald Ross and by Italian scientific men just as the nineteenth century came to a close. One must not forget, however, that the involvement of the cattle tick (*Boophilus annulatus*) as the intermediate host of Texas cattle fever (*piroplasmosis*) by Smith and Kilbourne in 1892–1893 constituted both a landmark and an inspiration for all subsequent workers in the arthropod transmission of disease. Furthermore, the elaborate demonstrations by Arthur Looss at the beginning of the present century (1905–1911) of the life cycle of the hookworm and its route of migration through the human body served as a masterpiece for all subsequent studies in helminthology.

The first accurate description of a pathogenic protozoan parasite was that of Lösch (1875), who discovered the pathogenic ameba (*Endamoeba histolytica*), described the associated symptoms and pathology, and in the course of his studies inoculated dogs with the infective organism. This was the first experimental work in parasitic protozoology.

Significant Advances in Human Parasitology Based on the Experimental Method

It now seems appropriate to review in brief a few of the significant developments of parasitology due to the use of the experimental method.

(1) *Amebiasis.* Following the initial work of Lösch (1875) in the use of the dog as an experimental host for the pathogenic ameba (*E. histolytica*) Kartulis (1885–1891), Kruse and Pasquale (1894), Hlava (1887) and Harris (1901) all used experimental animals, including dogs, cats, jumping mice, guinea-pigs and rabbits, in attempts to elucidate the life cycle of the organism. It remained for Walker and Sellards (1913) by the use of human volunteers to show that free-living amebae and *Endamoeba coli* were non-pathogenic and that amebic enteritis, including dysentery, developed in a high percentage of individuals inoculated by mouth with ripe cysts of *Endamoeba histolytica*. The later experimental work of Kessel (1928) on kittens and pigs, of Dobell (1931) on monkeys and kittens, of Hegner and his colleagues (1932) on monkeys and of the writer (1930–1932) on dogs has done much to elucidate the method by which infection is initiated, the lytic action of the organism and the lesion which it develops. These investigations have also served to demonstrate that all strains of *E. histolytica* are potentially pathogenic, but that infected individuals may at any one time have symptoms of dysentery, chronic enteritis, vague intestinal or systematic symptoms or may be symptomless carriers.

Very important in the development of our knowledge of this organism has been its cultivation in the test-tube, which was first announced by Boeck and Drbohlav in 1925. This technique initiated studies on encystation and excystation and the nuclear divisions at the time of and subsequent to excystation [Yorke and Adams (1926), Dobell (1925,

1928)]. Furthermore, Cleveland and Sanders (1930) have also obtained bacteria-free cultures of organisms but have apparently shown that the ameba will not propagate in the test-tube in the absence of certain bacteria. Finally, Craig (1928, 1931), by demonstrating the systematic reaction to *E. histolytica,* in the form of antigenic substance in the blood serum, has developed a highly successful method for determining the presence of the organism in the bowel and for following the reaction of the body to the organism.

(2) *Malaria.* It has already been stated that the inspiration for the epochal discovery of Ross was the work of Manson and Manson's hypothesis of the mosquito transmission of this disease. Ross as a young army surgeon in the face of almost insuperable obstacles successfully demonstrated that the mosquito was the intermediate host and transmitter of this parasite. After three years of partial success (1895–1897) with the estivo-autumnal human infection Ross was transferred to a non-malarious area, but studied the development of another plasmodium in birds and succeeded in transmitting it from naturally infected birds through the mosquito to parasite-free birds (1898). The complete development of the human malaria parasites was demonstrated in Italy by Bastianelli, Bignami and Grassi in 1898 and by Manson in London in 1900. That protection from malaria is provided by screening from anopheline (dapple-winged) mosquitoes was first shown by Low, Sambon and Terzi in the year 1900 in an experimental hut set up in Italy at the suggestion of Manson.

With the acceptance of the mosquito-transmission of malaria, work was initiated in various parts of the world where malaria is rife, to determine the anopheline mosquito hosts of the infection, both in nature and in controlled laboratory tests. In this way several dozen species of the genus Anopheles have been incriminated. It has been found, however, that all species capable of transmitting malaria in the laboratory are not necessarily equally important under natural conditions, and that a dangerous mosquito host in one country, as, for example, *Anopheles ludlowi* in the Federated Malay States, may not be similarly important in the Philippines, where it also abounds. Here in our own area there are four or five anophelines, but only one, *Anopheles quadrimaculatus,* is responsible for malaria as a wide-spread infection in the South.

The introduction of the malaria plasmodium as a therapeutic agent in paresis by Wagner von Jauregg (1924) has opened an extremely important field for experimental study of the effects of the organism in the human body under controlled conditions, so that it is now possible to observe the development of the infection from the time of inoculation until the infection is naturally controlled or until chemotherapy is instituted. The studies of James (1926–1927) in England and of Boyd (1932) in Florida, in rearing anophelines, infecting them with known strains of malaria and later inoculating non-immune paretics, has filled in many of the gaps in our knowledge of the interrelationship of parasite and hosts.

Working along other lines Clark (1929, 1930) in Panama and recently Knowles (1932) in India have studied malaria in monkeys. Knowles has found a monkey type of malaria which is fatal to a certain species of monkey, apparently symptomless in another monkey and produces marked symptoms in human volunteers. In one host it is morphologically similar to the human tertian malaria plasmodium, in another, to the human quartan malaria species and in still a third has some of the characters of the estivo-autumnal parasite.

This study has just been announced but promises remarkable opportunity for undertaking investigations on host-parasite relations. Growing out of Clark's work (*vida supra*), Taliaferro (1932) has studied the host-tissue reaction in monkey malaria and has demonstrated experimentally much that has been surmised but never proved in human infections.

On the therapeutic side within the past fifteen years tremendous efforts have been employed to develop experimentally satisfactory substitutes for quinine. Out of the hundreds of synthetic compounds studied plasmochin and recently atebrin have been found to give promise of definite use.

In the field of malaria control, aside from therapeutic prophylaxis, intensive experiments have been made in attempts to prevent the breeding of malaria mosquitoes. The introduction of the little fish Gambusia and the water-weed Chara into mosquito-breeding waters have been natural experiments of no small merit. Oiling of the breeding places and dusting with Paris green have required infinite study to determine the most suitable materials, the best technique and the practicability of each method.

Thus malaria, the greatest scourge of mankind, has tested the ability of the greatest men of our times. Accomplishments in this field have been almost exclusively experimental in character.

(3) *Trypanosomes.* The discovery of the trypanosomes in Africa, first in cattle by Bruce (1895), then in man by Forde (1901, *Trypanosoma gambiense*) and by Stephens and Fantham (1910, *T. rhodesiense*) opened the way for demonstration of the tsetse flies as intermediate hosts and transmitters of these infections (Kleine, 1909; Kinghorn and Yorke, 1912). The two human species morphologically indistinguishable in man, have been shown by murine inoculation to be differentiable in this experimental host. Meanwhile Chagas (1909) showed that South American trypanosomiasis was transmitted by a reduviid bug, *Triatoma megista.* The investigations of Dr. Louise Pearce on the trypanosomicidal properties of an arsenical preparation, tryparsamide, first in rats and later in human cases, might conceivably be taken from a modern Arabian night's tale, were it not known as fact.

(4) *Rickettsial infections.* We are all more or less familiar with the sacrifices of life that have been made to typhus fever, with its tremendously high mortality. Not till 1909 did the distinguished French investigator, Charles Nicolle, demonstrate that body lice played a rôle in the transmission of this infection. Another rickettsial infection with high mortality, Rocky Mountain spotted fever of our own Northwest, was shown by Ricketts (1906) to be transmitted by a tick, *Dermacentor andersoni.* Recently Parker, of the U. S. Public Health Service, has developed a vaccine which affords relative protection from this dread disease. In far-off Japan a serious fever which broke out in the lower river valleys in springtime was first described by Baelz in 1879. Believed by the country folk to be associated with a little red mite, *Trombicula akamushi,* experimental work on rodents and monkeys has amply demonstrated this hypothesis, while Nagayo (1931, 1932) has shown that the organism belongs to the Rickettsia group. Pseudotyphus of Sumatra has also been found to be transmitted by a red mite, while Brill's disease and endemic typhus in the United States have just recently been found to be disseminated by rat-borne arthropods (mites and fleas).

(5) *Yellow fever.* Who of us is not familiar with the experimental studies on yellow fever in Havana by Reed, Carroll, Agramonte and Lazear (1900) and

the proof that the tiger mosquito was responsible for this plague of all our Southern ports? With their proof in hand Havana, the Canal Zone, New Orleans, Mobile and Charleston were made safe for human existence. The recent work of Stokes and his associates (1928 *et seq.*) in demonstrating the susceptibility of the macaque to this infection has made it possible to study the virus of this disease and to prepare a vaccine which is at least partial protection for non-immune human beings.

(6) *Hookworm infection.* Probably next to malaria hookworm disease is the most wide-spread parasitic infection that has caused the death of untold millions and has been responsible for incalculable social and economic loss. The discovery of the worm by Dubini in 1838 was followed by significant findings by Grassi in 1878, Perroncito in 1880 and Leichtenstern in 1886–1887. These led by orderly sequence to the experimental studies of Looss, initiated in 1896 and concluded in 1911, which provided us with a complete story of the development of this worm parasitic in the human body and free-living in the soil, and the method of human inoculation through the skin. Looss used dogs primarily for his experimental studies, but submitted to infection himself, in order that he might have more intimate knowledge of his problem. Following the development of a simple apparatus by the Dutch investigator, Baermann (1917), for isolating the hookworm larvae from the soil, Cort and his students (1921) began an extensive investigation in the laboratory and in the field to determine the bionomics of the hookworm. It is now possible by egg-count methods to estimate the worm-burden in an infected human being. The development of the free-living stages under different conditions of soil, moisture and temperature is now known. It has also been discovered that animals on a deficient diet are most susceptible to infection (Foster and Cort, 1932) and that animals on a balanced diet gradually acquire an immunity to the infection, so that reinfection becomes more and more difficult. Creeping eruption, a skin infection common in Florida and extending throughout the Gulf Coast, has been found to be due to a hookworm, *Ancylostoma braziliense,* which commonly infects dogs and cats along our Southern shores but is less adapted to man as an intestinal infection.

In the development of drugs for the eradication of hookworms carbon tetrachloride was first advocated by Hall and his colleagues (1921) as a good anthelmintic for dogs. Human trial was initiated by Leach (1922) on condemned prisoners in Ceylon. With the extensive use of this potent vermifuge a few fatalities resulted from its administration. Lamson and Minot (1928) have shown that this, like eclampsia, is due to histamine poisoning when there is an inadequate supply of calcium in the blood. The more recent introduction of tetrachlorethylene and hexylresorcinol as hookworm therapeutics in human medicine has been preceded by careful pharmacologic studies on dogs and other laboratory animals.

(7) *Ascaris lumbricoides.* The common roundworm of children has been known since ancient times. Only within the past twenty years, however, has its life history been revealed. Thanks to the experimental work of Stewart (1916) and of Ransom and Foster (1917) and Ransom and Cram (1921), we now have proof that the ripe egg, when swallowed, hatches in the duodenum, and that the emerging larva penetrates the intestinal wall to the mesenteric blood vessels or lymphatics, is carried through the right heart to the lungs and works its way out of the capillaries into the air passages, is carried up to the epiglottis, migrates down the

esophagus and finally within the small intestine develops to the adult stage. The lung symptoms, during the passage of the larvae through this organ, were definitely corroborated by two Japanese volunteers who submitted themselves to experimental infection (1922) and at the appropriate time developed a typical "Ascaris-pneumonia." Recently Cort and Otto (1929 *et seq.*) have carried out extensive epidemiological studies on Ascaris, comparable to the earlier hookworms investigation of Cort and his students. These have shown how and why the infection is essentially one of childhood, since the ground around unsanitated homes is seeded with developing eggs which are passed in the stools of infected children. The pharmacological studies of Lamson (1931) on the specific vermicidal properties of hexylresorcinol for Ascaris infection constitute one of the recent contributions to experimental therapy.

(8) *Strongyloides.* The minute nematode, *Strongyloides stercoralis*, which parasitizes the tissues of the upper intestinal tract, is another example of a parasite for which information has been acquired by the experimental method. Discovered by Normand in 1876 and described by Bavay in the same year, the worm was shown by Leuckart (1882) to have both a parasitic and a free-living phase. At times the free-living phase was short, as in the hookworm; at other times a complete reproductive cycle developed outside the body. Extensive experimental work of Fülleborn (1914) and by Sandground (1926) has elucidated the migration route through the blood stream and lungs and has indicated that climate is not entirely responsible for the extent or type of the free-living phase (whether direct or indirect in mode of development). Recent work of the writer and his associates (1931 *et seq.*) has demonstrated for the first time the parasitic male, which apparently fertilizes the parasitic female and then dies or is passed in the stool. A hyperinfective mode of development has also been observed, wherein the larvae by a telescoped type of development mature to the infective stage before passing out of the bowel and are capable of producing a hyperinfection of the patient. The speaker has also experimentally confirmed and elaborated the work of Sandground in showing the instability of types of development and their mutability from one type into another, especially from the indirect and hyperinfective types into the direct type.

(9) *Filarial worms.* From 1875 when Manson found larvae of Bancroft's filaria circulating in human peripheral blood at night, the life history of this worm and its clinical manifestations have been a puzzling complex of fact and theory. Except for the transmission of this worm from man to man by the bite of certain mosquitoes which serve as intermediate hosts little is even now understood of its relationship to its human host. Within recent years the transmission of other human filarial worms, including the loa worm (*Loa loa*), the persistent filarial worm (*Acanthocheilonema perstans*) and the convoluted worms (*Onchocerca volvulus* and *O. caecutiens*), has been shown to take place through the bites of blood-sucking flies. The studies of Strong (1930–1932) and of Hoffmann (1930, 1931) on *Onchocerca caecutiens* have added the latest knowledge to this infection as it exists in Guatemala and in Southern Mexico.

(10) *Tapeworms.* Certain of the human tapeworm life cycles were first demonstrated during the middle decades of the past century. Others were not completely elucidated until a few years ago. The life cycle of the broad fish tapeworm, *Diphyllobothrium latum*, was first fully demonstrated in 1917, although it had been known for many

years that infection by man was acquired by eating infested raw fish, and final confirmation of the hypothesis, that the dwarf tapeworm, *Hymenolepis nana,* requires no intermediate host, was not forthcoming until 1924.

(11) *Trematodes or flukes.* Reference has been made to the experimental demonstration of the life cycle of the sheep liver fluke by Leuckart in 1882 and independently by Thomas in 1883. For another quarter century no other fluke infection of economic importance to man was elucidated. Cumulative experimental data by Japanese investigators on the Oriental blood fluke, *Schistosoma japonicum,* culminated in the demonstration by Miyagawa in 1912–1913 of the route of migration of this worm through the human body and by Miyairi and Suzuki (1913–1914) of the extra-human phases of development of this worm. This was followed (1915) by Professor Leiper's demonstration of similar life cycles for *Schistosoma haematobium* and *Schistosoma mansoni* in Egypt. Meanwhile Japanese workers had shown that the liver fluke, *Clonorchis sinensis,* was acquired from eating raw fish and the lung fluke, *Paragonimus westermani,* from consuming uncooked crayfish and crabs. It remained for an American missionary physician in China, Dr. C. H. Barlow (1923, 1925) to elucidate the life cycle of the large intestinal fluke, *Fasciolopsis buski.* Having observed that patients suffering from this disease in his hospital came from a certain district, he went to the area in question and after careful investigation eliminated all probable sources of infection except two water plants (the water "chestnut" and the water caltrop), the products of which were commonly consumed raw. With this beginning he finally incriminated not only these plants but also certain snails which lived in intimate contact with the plants. Finally, to confirm his fully developed theory, that the larvae of this fluke encysted on the edible parts of the plants and were accidentally swallowed by human beings, he submitted himself to infection, and after three months was able to recover eggs of the parasite in his stool. Later the worms were recovered after administration of an anthelmintic, but not until marked toxic symptoms of the infection had developed.

The Ethics of the Experimental Method

In most experimental work with human parasitic infections laboratory animals can be utilized for all practical experimental tests, thus obviating the need for and potential risk by human volunteers. Such laboratory animals should necessarily be treated with the greatest kindness and every effort should be made to avoid pain. One careful worker has stated that he always cared for his experimental animals himself, and even gave more thought and attention to their comfort and happiness than to his own health. If monkeys had been known to be susceptible to yellow fever and had been utilized by the Yellow Fever Commission in Havana (1900) unnecessary sacrifice of life would have been avoided. Yet in certain crucial types of experimentation it has been found highly desirable to know if human host-parasite relationships are directly parallel to those of susceptible experimental animals. Our knowledge of these infections is much richer and much surer by virtue of volunteer and, at times, accidental human infection. This is particularly true of amebiasis, trypanosomiasis, leishmaniasis, hookworm infections, ascariasis, tapeworm infections, Fasciolopsis infection and Dr. F. G. Cawston's accidental self-inoculation with the infective larvae of

the blood fluke, *Schistosoma haematobium*.

The experimental study of human parasitic infections, both in experimental animals and in the test-tube, is often fraught with imminent danger to the experimenter. Yellow fever, typhus, Rocky Mountain spotted fever, relapsing fever and tularemia are the most conspicuous examples of diseases in which some slip in experimental technique, known or unknown, has resulted in the death of the investigator. Fortunately, vaccines are now available at least as a partial protection against some of these infections, and others will undoubtedly be developed.

Has the Experimental Method Outlived its Need in Parasitology?

It might seem from the foregoing enumeration of instance after instance, where important gaps in our theoretical and practical knowledge have been supplied by experimental demonstrations, that all the important problems dealing with human parasites have been solved. Possibly the most dramatic work has been accomplished, but much remains to be done. Among some of the unsolved problems the following will serve as examples.

I. The question of susceptibility or immunity to homologous or heterologous strains of the same parasite and to apparently physiologically different strains of the same organism.

II. The predilection of parasites for certain tissues of the body.

III. The problem of latency in malaria.

IV. Periodicity of the microfilariae in Bancroft's filarial infection.

V. The lung phase in hookworm, Ascaris and Strongyloides infection.

VI. Is *Endamoeba histolytica* always a tissue parasite? If so, why are 90 to 95 per cent. of infected individuals apparently symptomless carriers?

VII. Problems arising from the apparently spontaneous development of newly recognized diseases, such as Brill's disease and endemic typhus, and Rocky Mountain spotted fever in the Eastern United States.

No, the experimental method has not outlived its usefulness. Its utilization will be the means of supplying an increasing amount of valuable and necessary additions to human knowledge, with the consequent alleviation of suffering and distress.

BIBLICAL BOTANY AND ARABIC LORE

By EPHRAIM HA-REUBENI

SECTION OF BIBLICAL BOTANY AND PLANT LORE, HEBREW UNIVERSITY, JERUSALEM

It must not be forgotten that the ancient Israelites, both the common folk and the teachers of the people, were a nation of husbandmen and herdsmen and made extensive use of plants not only for food and condiments, pasture for their cattle, for medicines, poison, laundry, dyeing and cosmetics, but for religious purposes on occasion of festivals and mourning. References to the plants growing on hills and in valleys of Palestine illustrated their folk-lore and parables. Flowers and trees gave their names to various places in the land and to the sons and daughters of the prophets and sages. In the course of their work in the vineyards and fields, and in valleys and on the seashore, at every season of the year, they observed many details of the various forms of the plants, and they learned to recognize and note their botanical development in different regions of the country. They even experimented in plant biology.

It is also imperative that intelligent inquiry be made into the Jewish and Arab plant lore of present-day Palestine and in neighboring countries. Such investigations can sometimes best be carried on in the tents of the Bedouins, in the herdsmen's booths and in humble fishing hamlets. In the course of many years' practical research on Biblical plants and plant lore, the importance of a close study of the plants of the Biblical and post-Biblical literature has therefore become increasingly clear in order to understand the words of the prophets and sages,—not merely for comprehending the bare text, but the ideas and emotions which swayed the prophets and the teachers of the people,—ideas frequently expressed by aid of the flora. Failure to appreciate the subtleties of botanical references is often the cause of distortion of the words of the prophets and results in the most erroneous explanations of the text. The plants in the Talmudic literature likewise are sometimes inaccurately described.

The great work of investigating the flora of Palestine, the plant lore of Palestine and neighboring countries and of the whole of ancient literature involves journeys into the fields and the valleys, into tents of the herdsmen, and again, turning from the fields and villages, to the many books published on the subject in Palestine and neighboring countries. Such investigations can not be carried out by scholars who come to Palestine for a limited period. Such work of necessity must actually be done in Palestine. It must be performed uninterruptedly for a period of many years.

An institution like the Hebrew University of Jerusalem, situated as it is, in the heart of Palestine, is peculiarly well equipped for this work. The section of Biblical plants and plant lore forms an important part of the work of the botanical department of the university. Attention must be drawn to the fact that the investigation of oriental plant lore is not only important as a help to understand ancient literature, but also as a study in itself, which must of necessity be of value as an aid in probing into the life of the orient, much less known to us than is supposed.

The study of the plants of Palestine from three points of view—Biblical, historical and botanical—may be termed "humanistic botany."

However, "humanistic botany" in Palestine, interesting in itself, must also serve through the Hebrew University the biological sciences in Palestine. The section of Biblical plants and plant lore of the young Hebrew University, not yet

fettered with the shackles of rigid tradition, is fostering the work of the section of Biblical plants and plant lore through research and through exhibitions which make the collections available to scientific men and to laymen. Exhibits of the plants are appropriately arranged in the museum, happily termed "The Museum of Plants of the Prophets and Sages and Plant Lore." The exhibits are arranged so that the plants and their component parts are preserved in their natural shape and color.

It is the only museum in the world where plants are shown in this manner. Mrs. Ephraim Ha-Reubeni, who has charge of this part of the work, has invented a series of new methods for such preparation of the material.

The artistic mounting of the plants in the museum in their natural shapes and colors is not only for beauty alone, but for the purpose of studying the morphology of plants and their parts in a minute and faithful manner. The labels giving explanations of the plants are arranged in Hebrew, Arabic and English, and in the course of time they will be printed in other languages also.

Many of the plants are arranged in their various forms of development from the time when they show their first petals until the blossoming and fruiting, and are exhibited so as to appear in their natural color and bloom.

In the plant lore branch of the museum is collected flora of the present day known to the Jews in Palestine, Syria and Iraq. A special hall has been set aside for Arab plant lore, which contains plants used for human food and fodder for cattle, various plants for industrial purposes, for medicinal purposes, poisons, fuel, for bird catching, fishing, graveyard plants and flora found in folk-lore and sayings.

To a great extent references to many matters in our ancient literature can be made more understandable by this collection of plants familiar to the native Jews and Arabs of our day. The ways of life of the people in Palestine and especially of the fellaheen and Bedouins, herdsmen and fishermen, have not altered materially from that of the Biblical and post-Biblical days.

In addition to lectures given at stated times in the university itself, requests are often received from both the botanical and historical point of view, from various parts of the country, from towns and settlements and especially from groups of workmen, for lectures on the plants found in their vicinity. These requests are fulfilled in so far as the means for such extension work by the department permit, and a number of addresses have been given, both for the Jewish colonists and their Arab neighbors, on the plants of the Bible and Talmudic times. One of the eventual hopes of the department is to arrange exhibitions of Palestinian flora which may be shown as traveling exhibitions in the countries of the Near East, perhaps even in Europe and America. The Hebrew University possesses the largest herbarium of Palestine plants in existence, and exchanges have already been effected with scientific institutions abroad of the first centuria in Palestine.

In addition to the work of research in this branch of botany, in which the writer has been engaged for the past twenty-five years, a popularization of the work has been attempted not only through exhibits in the Near East, Central Europe and the United States, but through collection of articles and drawings in realistic colors, with typical photographs.

A "Garden of the Prophets," in which an attempt will be made to show all plants and trees mentioned in the Bible and Talmud, is part of the plan of the Hebrew University to develop this side of its botanical work.

SURFACE TENSION

By Professor W. C. HAWTHORNE
CRANE JUNIOR COLLEGE, CHICAGO, ILLINOIS

Who of us have not enjoyed with our children the delightful adventures of Alice in Wonderland? And of all these, which is more amusing than the tale of the magic cakes which had the power of changing her size? I have often wished that our delightful spinner of tales had kept her of diminutive size for a little while, and given an account of her probable adventures. Many of them would have been all but unbelievable, while yet the author remained strictly within the bounds of sober scientific fact.

For instance, if she had shrunk down to a height of two inches, she would have had no end of trouble in getting a drink from any cup of commensurate size, say one sixteenth of an inch in diameter. Such a cup could not be filled with water. When she dipped it below the surface, the water would simply stretch over the top, like a rubber membrane, and refuse to enter. Or, the cup once filled by some means or other, the water would refuse to run out.

Were she to become a little smaller, she would be able to walk over the surface of this same strange liquid dry-shod. Perhaps it would be safest to wear snowshoes and, provided they were dry when she stepped out on her stroll, she would be in little danger. Once let the shoes get wet, however, and she would be lost. It would be as difficult to break through the surface from below as from above, and however good a swimmer she might be ordinarily, she would find the same surface dragging on her every movement as if she were swimming through the thickest morasses. However, underwater swimming would present no difficulty. It would be only when she came up for air that the drag would be noticeable.

Put in this way, these properties of a liquid surface seem only an amusing fancy, but it is a question of life or death to myriads of the tiny creatures that swarm beneath our feet. Grasshoppers get their "drinks" from the dewdrops on the stems of plants; they dare not (at least do not) sip from the edge of a pool. Were they to do so and fall in, their fate would be sealed, and the same is probably true of other insects. Baby mosquitoes stick up their "tails" through this (to them) rubbery surface layer, open out a few hairs and hang there as safely as the oriole hangs in her swaying nest, with the advantage, of course, that they can let go and scuttle to safety at any instant, and the disadvantage that when the health officer comes along and spreads a thin film of oil over the water surface its strength is not able to support them and they perish for lack of air.

You may satisfy yourself as to the existence of this strong surface film by laying a dry needle carefully on the surface of water. Being of steel, heavier than water, it ought to sink; but it does not. On the contrary, you will notice that the water surface is depressed below it, forming a little cradle, so to speak, in which the needle floats. The witches who went to sea in a sieve depended on this property, as you may prove for yourself with a little boat made of wire gauze. Each wire will behave as did the needle, and the film stretching from one to the other will support a considerable weight. But—make sure the boat is dry. To make sure that

it will stay dry, best dip it in melted paraffin, shaking the surplus wax from the wires before it cools, but leaving a thin coating over each wire. Such a boat will not only float, but in it considerable water may be carried safely, provided that the film retains its continuity, like a thin membrane stretched over the wires. Let it be broken, *i.e.*, let the wires themselves get wet, and the magic property is gone. A loosely woven coat is impervious to any ordinary shower because of the water film formed on the surface, stretching from one fiber to the next. So, too, it is not the cloth of the tent that keeps out the rain but the film covering the interstices. If this film be broken, say by touching the surface from the under side, a leak promptly develops. The water-shedding power of the tent may be improved by "painting" it with a solution of paraffin in gasoline. This does not stop up the holes, but leaves a thin coating of wax over the individual fibers. Then they do not become wet, as they otherwise would in time and no longer support the film.

Here is another apparently unrelated phenomenon that really depends upon these unsuspected forces resident in the surface of liquids. The lower end of a piece of porous material, such as loosely woven cotton cloth, is allowed to dip into water. Soon the entire cloth is wet, and a surprising amount of water will rise through it in a short time.

Once again, who would imagine that "pouring oil on troubled waters," a device still used by mariners for smoothing out dangerous waves, and the manufacture of shot also depend on the same property of liquid surfaces as these other phenomena mentioned? Shall we look into the philosophy of the problem a little?

Cohesive Forces in Liquids

It is very evident that forces are at play within a liquid which we ordinarily think nothing of. We have no trouble in recognizing and measuring cohesive forces in solids; they are not so evident in liquids; in fact, "as weak as water" is proverbial. But the forces are there, of surprising magnitude when we come to measure them—forces which pull the molecules together into as small a space as possible, and that of course is a sphere. To make shot, the melted lead is poured from the top of a high tower. It breaks up into perfectly spherical drops which fall into a tub of cold water and solidify before they have a chance to become distorted. A raindrop is spherical because every one of the billions of molecules constituting it is trying to get as near as possible to every other molecule. The same amount of water at rest is pulled out of shape by the force of gravity and the attractive forces between the molecules of water and the surface on which they lie. If the surface is not wet by the liquid, quite large drops may assume the normal shape of a liquid—spherical—as may be shown by drops of mercury or even of water on a dusty surface.

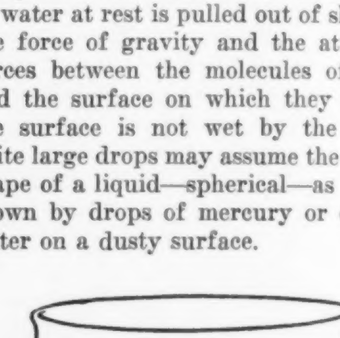


Fig. 1. Drop of aniline 1 inch in diameter floating in salt water.

Whenever a liquid is relieved from the distorting influence of other forces, so that it is not pulled out of shape by its weight, it takes this spherical form. Here is a large drop of aniline in a vessel of salt water of equal density, and you see the same tendency at work here.

Measurement of Liquid Cohesion

When we attempt to measure those attractive forces directly, we encounter many difficulties. This has been one method: A long barometer tube has been carefully cleaned with sulfuric acid, then filled with mercury which has been boiled to drive out the air. Now when this is inverted, with the open end below the surface of mercury in a dish, we expect the column to fall to a height of thirty inches or less, this being the height of the barometric column sustained by air pressure. But Professor Osbourne Reynolds found that twice this height was sustained even when an air pump was applied to the lower end of the tube and the pressure there was exhausted to a very low amount. The sulfuric acid stuck to the upper end of the tube and the mercury to the sulfuric acid, and the rest of the mercury simply hung from the upper end like a chain of weights, indicating a minimum tensile strength of thirty pounds per square inch. Whenever a break did occur, it was because of a tiny bubble of air, which had the same effect as a nick in the edge of a ribbon under a strain. The break started

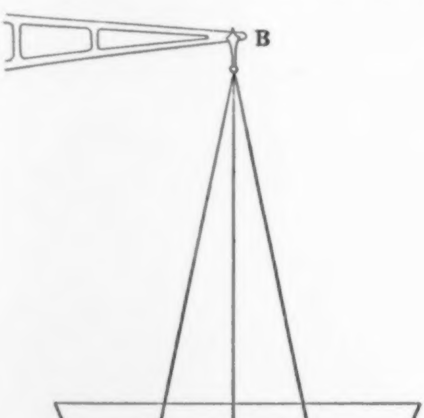


Fig. 2. Glass plate P being pulled away from water by balance B.

there. Other methods have shown that the internal stress in a liquid must be reckoned as many times greater than indicated here.

For water, we can easily prove the existence of such a stress by allowing a flat disk of glass, suspended from a spring balance, to touch the surface. The under part of the glass must be well cleaned with soap, then nitric acid and finally pure water. We shall see that a considerable force is required to pull the disk from the water, and since a film of water adheres to the surface of the glass it is plain that we have not overcome adhesion between glass and water, but cohesion between molecules of water.

Sphere of Influence

Supposing that there is an attraction between the molecules of a liquid, even if nothing but the well-accepted force of gravity, it must fall off rapidly with distance; at least, inversely as the square of the distance, and many investigators think it may vary as the 4th power of the distance. Granting this, it is evident that an imaginary sphere could be drawn around every molecule, outside of which this force is practically nil. This is called the sphere of influence of that molecule, and though very small must contain many score, perhaps hundreds, of molecules, all pulling upon the molecule at the center and in turn being attracted to it. As long as the molecule is well within the confines of the liquid this pull is equal in all directions, which is the reason it is so difficult to measure in ordinary ways.

At the Surface

But suppose the molecule, in its erratic motions through the body of the liquids, approaches the surface, so that a part of this sphere of influence projects above the surface, into a region where there are no or few molecules. It is evident that the pull downward is now

greater than the upward pull, so that the molecule is pulled back into the body of the liquid, unless it is moving so fast that its kinetic energy suffices to pull it away from this backward attraction. This last is what happens in evaporation, and since only the more rapidly moving

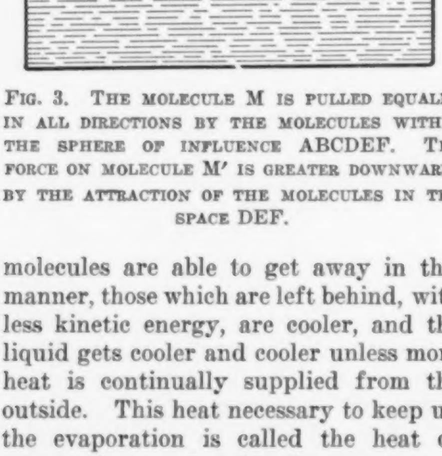


FIG. 3. THE MOLECULE M IS PULLED EQUALLY IN ALL DIRECTIONS BY THE MOLECULES WITHIN THE SPHERE OF INFLUENCE ABCDEF. THE FORCE ON MOLECULE M′ IS GREATER DOWNWARDS BY THE ATTRACTION OF THE MOLECULES IN THE SPACE DEF.

molecules are able to get away in this manner, those which are left behind, with less kinetic energy, are cooler, and the liquid gets cooler and cooler unless more heat is continually supplied from the outside. This heat necessary to keep up the evaporation is called the heat of evaporation, and evidently must vary with the attraction between the molecules.

It is evident then that the molecules near the surface of a liquid are in a different condition from those in the main body, in that the former are being pulled back into the liquid by the attraction of the molecules below. This results in an increase of density in that part of the liquid near the surface, and within this thin layer (not thicker than the diameter of the imaginary sphere of influence) such curious phenomena arise as were mentioned in the beginning of this chapter.

Surface Tension

Evidently it is of little difference whether we think of this force as being applied from within or without, and we are accustomed to say that the surface of a liquid acts as if it were covered with an elastic film under a tension, *i.e.*, continually trying to contract, so a drop of liquid, like a balloon, must assume a spherical shape, with the surface film taking the place of the rubber.

There is this difference to be noted, however, between the action of the rubber and of the surface film. When we stretch the rubber, we are pulling the molecules farther apart, and the force increases with the stretch (Hooke's law); but when the surface film is stretched, as when we blow a soap bubble, we are simply bringing more molecules to the surface, and the tension does not increase. The constant force that must be exerted at right angles to a line one centimeter long in the surface of a liquid to keep it from contracting is called the surface tension. It varies with the internal stress which is its cause, but is only an infinitesimal fraction of it.

Measurement of Surface Tension

When we dip a rectangular wire frame into a liquid and then withdraw it care-

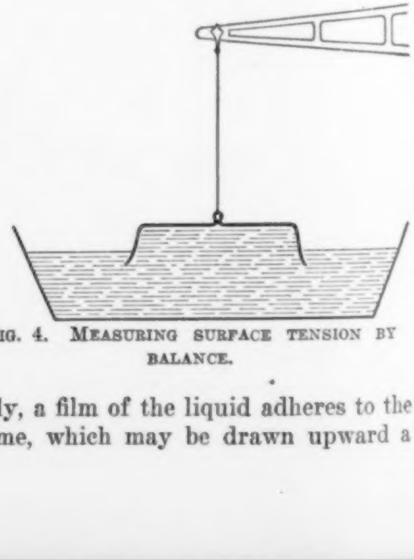


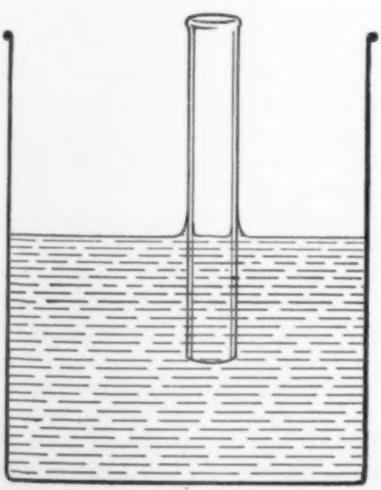
FIG. 4. MEASURING SURFACE TENSION BY BALANCE.

fully, a film of the liquid adheres to the frame, which may be drawn upward a

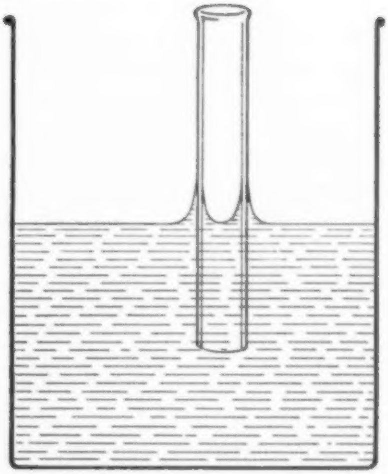
quarter of an inch or more before the film breaks. If the frame be attached to a delicate balance, we can measure the force necessary to hold the wire frame in position and the extra force required when it is carrying the film, which is trying to pull it back below the surface. It is a delicate operation, but when we use pure water and divide the average of several trials by twice the width of the frame (since there is a film on each side of the frame) we get something less than 75 dynes per centimeter as the force required to rupture this film.

Capillarity

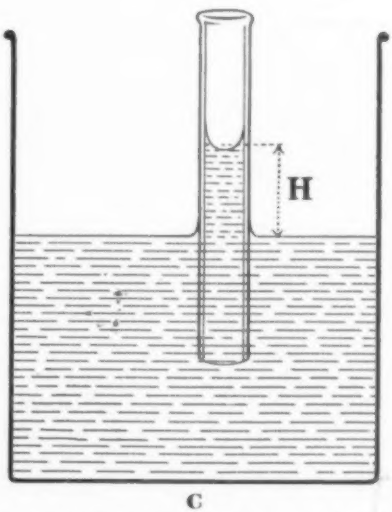
Let us look into the reason for the rise of water into the meshes of the cotton cloth. Water, as well as a good many other liquids, has the power of rising in small tubes (capillary, from Latin, *capillus*, "hair") far above the level of the liquid outside the tubes. Some liquids are depressed below the surface. It depends upon whether or not the liquid wets the sides of the tube —whether the power of adhesion is greater or less than the power of cohesion. Mercury in glass tubes gives the best example of the latter case. The cohesion of molecules of mercury for each



A



B



C

Fig. 5. Illustrating the rise of water in a capillary tube.

other is much greater than the adhesion of molecules of mercury for glass. But mercury *will* rise in a copper tube, since the adhesion of mercury for copper, with which it forms an amalgam, is very great.

Now suppose that a glass capillary is dipped into water. If the glass be free from grease or any dirt, a film of water immediately reaches up the inside of

the tube from the surface of the water. Owing to the tendency of the film to assume the smallest possible shape, it no longer remains as in Fig. 5 (A), but assumes a concave shape as at (B). This film continues to contract, pulling a column of water up after it, as in (C). This allows the film to reach up higher, and the column of water in turn is pulled higher. It is evident that this will go on until the downward pull of the water (its weight) is equal to the maximum upward pull which the film is able to exert. The weight of the water can be calculated: It is the volume $\pi r^2 h$, where r is the inside radius of the capillary, h the height of the liquid, multiplied by d, its density. The upward pull of the film is the pull, T, per centimeter of the length, which in this case is the inside circumference of the capillary; *i.e.*, the pull of the film is $T\ 2\ \pi r$. Equating these two expressions and solving for T, we have $T = \frac{1}{2} r\ h\ d$.

It is evident that the height to which the liquid rises in a tube which it wets is inversely proportional to the diameter, which fact can be easily verified by trying tubes of different sizes. This justifies the plea for frequent cultivation of the garden soil in a dry time, for by breaking up the cracks, we prevent the access of the drying air to the roots of the plants, and by making the interstices between the clods smaller, we increase the depth from which the water may rise by capillary attraction.

This tendency of a surface film to contract to the smallest possible dimensions is also shown by the behavior of a soap bubble. If the bubble is blown on the bowl of a pipe, a small but constant pressure must be maintained to prevent its shrinkage. Films may be formed on wire frames of various shapes, and they invariably take that shape that mathematically gives the minimum surface. Very interesting cases are discussed in that fascinating little volume, "Soap Bubbles and the Forces Which Mold Them," by Boys.

Effect of Impurities

Some substances increase, some decrease the surface tension. Alcohol is one of the former. Scatter a little fine cork dust over the surface of water, then bring down near the surface a rod wet with alcohol. Even before it touches the water, the particles will fly away as if repelled. The fact is that a little of the alcohol vapor is absorbed, and this so weakens the surface film at that point that the surrounding surface draws away, carrying the dust with it. An even more striking experiment may be performed with a little boat a couple of inches long, of paraffined paper. There must be a little compartment in the stern, with a number of openings to the rear. In this compartment put a wad of cotton wool wet with alcohol. Place the boat in a tub of water, and as the alcohol oozes out and diminishes the pull backward, it will move forward at a surprising rate—*pulled* from the front and not *pushed,* as boats usually are.

We are told (Prov. iii, 31) to beware of looking "upon the wine when it is red . . . when it moveth itself aright." Just what is meant by this expression? Well, the wine will creep up the side of the glass in a thin sheet, drawn by capillary attraction, but in this condition, evaporation of the alcohol will take place very rapidly. The more watery liquid left will have a sufficiently high surface tension so that it will be drawn together into drops which will run down the side of the glass, forming the "tears of wine." But this "moving itself aright" occurs only with wine that is 15 per cent. to 20 per cent. strength—strong enough to be intoxicating.

For my tonsilitis last winter, the doctor asked me to try a new remedy, "S.T." I asked him what the letters stood for, and he laughed and said "Surface Tension" and explained that its

significant ingredient was a chemical that so reduced the surface tension of the liquid that it reached down into the crypts that harbored the germs that caused the trouble. The medicines used ordinarily simply reached over the surface, as the film of water stretches over meshes of the sieve, as described above.

Camphor also diminishes the surface tension, and if a little crumb of gum camphor be dropped on the surface of *clean* water, it will spin about like a crazy water-bug. The little projections on the surface of the crumb dissolve most rapidly, and the tension is weakened most in that vicinity, so the camphor is drawn away in the opposite direction. In a moment, solution is occurring most rapidly at some other point, and the "bug" darts off in another direction.

But now, while the dance is most vigorous, touch the surface with the tip of your finger, which has been drawn over your hair. The motions stop instanter. The explanation is that a film of oil from the finger has spread over the surface of the water, so that the surface tension everywhere has been reduced to such a degree that the solution of the camphor no longer makes any difference.

Lord Rayleigh allowed a weighed drop of oil to spread over a surface of known area, and calculated that the thickness of the oil film when the motion of the camphor was stopped was two one-millionth of a millimeter. Half of this thickness produced very little effect; more than two millionths diminishes the surface tension slightly, not at all proportionally. Other experiments seem to show that at the critical thickness, there are just enough molecules to cover the surface one layer deep, and that the long oil molecule, consisting of a chain of carbon atoms, is standing on the end which forms a chemical union with the water molecule. A smaller amount of oil means that there are not enough molecules to cover the surface, so that we have practically a water surface; more oil means simply another layer of molecules on top of the first, but no essential difference in the character of the surface.

Soap (and alkaline substances generally) is another substance that diminishes the surface tension of water. The reason that it is so difficult to cleanse the skin with pure water is that the water forms a film *over* the particles of dirt. The presence of the soap so reduces the surface tension that water may be worked around and *under* the dirt, thus dislodging it. (There is also a chemical action, —emulsification of the grease by the free alkali of the soap,—and the adsorption of the dirt by the colloidal particles of the soap that help out. Washing your face is not a simple thing.)

If soap diminishes the surface tension of water, it may be asked why we can blow *soap* bubbles successfully, but fail with pure water. This involves energy considerations and will be discussed later.

Effect of Temperature

Surface tension decreases as the temperature increases. Here are two splinters of wood floating on the surface of water, a few millimeters apart. I touch the water between them with a red-hot wire, and immediately they fly apart. The surface tension between them has been weakened, and the unchanged pull in the other direction has pulled them apart. Perhaps you will remember a kettle full of not too greasy soup, wherein, while hot, the grease formed a thin layer on the whole surface, but as the soup cooled, collected in rather thick drops. The increased surface tension of the cooling grease pulled it together. This property explains the method of removing grease from a fabric. Put a piece of blotting-paper under the cloth and hold a hot iron over the spot. The difference in the surface tension of the

hot grease above and the cooler grease below causes it to become concentrated below, and it is drawn away into the blotter.

Let us look into the philosophy of this a bit. Surface tension depends, as we have seen, upon the attractive force between the molecules. But there is another force in action between these bodies. They are in rapid motion, and because of their elasticity, every collision causes a rebound—they are, because of this motion, being driven apart. This motion is no more or less than heat, and the temperature varies as the average of the square of the velocities, or the "mean square velocity" (which is different from the square of the mean velocity). Here we see an explanation of the well-known fact that bodies expand when heated. Evidently two opposing forces are at work here, and the decrease of surface tension with the rise of temperature follows necessarily.

Evaporation is merely the escape of the more rapidly moving molecules through the surface, as before said.

The addition of these flying molecules from the liquid to the space above the liquid produces a pressure of its own called the vapor pressure of the liquid. Of course it rises with the temperature, and when the pressure has become equal to that of the atmosphere (14.7 lbs. per square inch) we have reached the boiling-point of that particular liquid. Provided we supply heat fast enough, vapor is emitted from the liquid in sufficient quantities to push the atmosphere away, and the space above the surface is occupied solely by the vapor of the liquid. But no matter how fast we supply heat, the temperature does not rise any more, for as fast as the molecules reach this temperature, they escape through the surface.

It is evident from this discussion that we should expect a close connection between the boiling-point and surface tension. The following table illustrates this:

	Boiling-point	Surface tension
Ether	34.6° C	19.3 dynes
Alcohol	78.0° C	25.3 "
Benzol	80.2° C	30.6 "
Water	100.0° C	75.8 "
Mercury	357.0° C	441.3 "

Heat of Vaporization

I have said that it is impossible to raise the temperature above the boiling-point. This is not strictly correct. It is possible, provided you prevent the escape of the more rapidly moving particles. But this raises the pressure, as the steam engineer very well understands. At 180° C., if the steam is confined, the pressure is nearly ten times what it is at 100° or the ordinary boiling-point.

It is evident that the heat energy needed to vaporize one gram of water, what we call the latent heat of vaporization, amounting to 540 calories, is work that is required to do two things: (1) Push back the atmosphere from the space to be occupied by the steam and (2) tear the molecules away from each other or overcome this force of cohesion we have been speaking of. Let us call the science of arithmetic to our aid:

When the cubic centimeter (one gram) of water at 100° C. becomes steam, at 100° C., its volume becomes 1,672 cc., an increase of 1,671 cc. In doing so, it has to overcome a pressure of 14.7 pounds per square inch, or 1,033.6 grams per square centimeter, or 1,012,928 dynes per square centimeter. The work done is found by multiplying this pressure by the change of volume, 1,671 cc., and we get over 169 joules or about 40 calories. This leaves very close to 500 calories as the work that has to be done in pulling every molecule in a gram of water through the surface—away from the

counter attraction of its fellows. This would lift 120 pounds to a height of 6 feet.

Critical Temperature

This relation between temperature, external pressure and surface tension may be illustrated by a very pretty experiment. Within this little sealed glass tube, we have one gram of ether (Fig. 6). Above it, nothing but ether vapor. The air was driven out before it was sealed. The surface of the liquid forms that saucer-shaped meniscus which is characteristic of the liquid condition. Picture to yourself the molecular activity going on within this little tube; millions of molecules bumping about, colliding with each other, and darting off in a new direction. Some approach the surface, only to have their motion checked by the pull of the molecules behind them; others are going so fast that they break through, perhaps to be hit by other molecules already there and knocked back, perhaps to get away entirely; and, except for the fact that their mean free path now is perhaps a hundred times their own diameter, instead of three or four, there is no difference in our pictures of the ceaseless activity that is going on above and below the meniscus. Now I begin to heat the tube. As before explained, we are increasing the velocity of the molecules. You will notice (Fig. 7) that the volume of the liquid, in spite of the increased pressure of the vapor above it, is increasing; the molecules, therefore, must be getting farther apart. This means that the attraction between them is less, and the evidence of this is that the meniscus is flattening out. Note that while the density of the liquid is decreasing, that of the vapor above is increasing for two reasons: the volume is less and there are more molecules there. After a while we notice that the meniscus is nearly flat, and is becoming indistinct (Fig. 8). Soon it vanishes entirely, and we have in the tube—what? Gas or liquid? It is of the same density throughout, and consequently the surface tension has disappeared. We no longer have a liquid with its vapor; it is a gas. The temperature at which this change takes place is called the critical temperature for that substance. Above this temperature, no amount of pressure can convert the gas to a liquid.

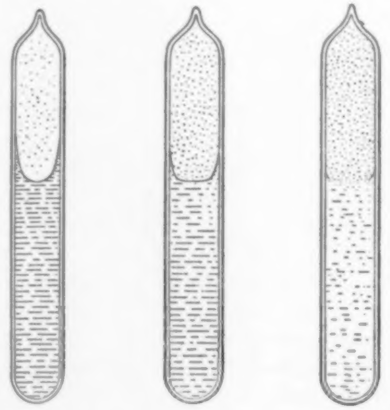


Fig. 6. Fig. 7. Fig. 8.

Capillarity and Hydrostatic Pressure

The rise or depression of liquids in capillary tubes may be explained in another way, although it comes to the same thing in the end. Let M (Fig. 9) be a molecule below the surface of a liquid. Ordinarily, it is pulled in all directions by the surrounding molecules within the sphere of influence. But if part of that sphere, say the portion *nop*, projects above the surface, the pull of an equal

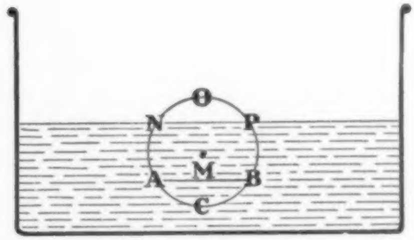


Fig. 9.

portion, *abc,* is now unbalanced and exerts a force, *p,* pulling the molecule back downward. This force is transmitted through the liquid, of course, so that the total force, P, below the surface, is not only that due to the weight of the liquid (which depends upon the height times the density, or *hd*), and the barometric pressure, *B,* but in addition this molecular pressure, *p.* Or in symbols, $P = B + hd + p$.

Now, suppose the surface is concave, *i.e.,* the liquid wets the tube, as in Fig. 10, M being the same distance below the surface as before. M is now pulled back by the molecules within the space *def,* a volume evidently smaller than *abc,* consequently *p is less beneath a concave*

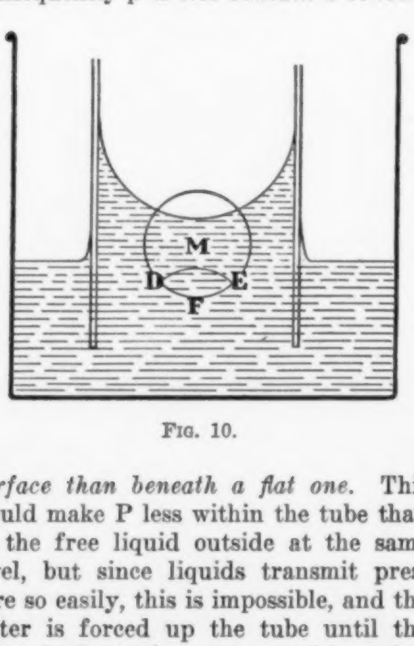


FIG. 10.

surface than beneath a flat one. This would make P less within the tube than in the free liquid outside at the same level, but since liquids transmit pressure so easily, this is impossible, and the water is forced up the tube until the extra hydrostatic pressure, *hd,* makes the pressure inside the tube equal to that on the outside.

A similar line of reasoning shows that below a convex surface (liquid does not wet the tube, see Fig. 11) the *pressure is greater,* consequently *hydrostatic pressure must be less* to balance conditions, and the *liquid therefore is depressed* in a tube which it does not wet.

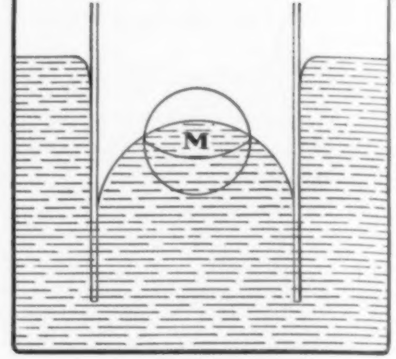


FIG. 11.

DROPS AND BUBBLES

The curvature of the surface is measured mathematically by the reciprocal of the radius of curvature, that of a flat surface being zero, since a flat surface may be looked upon as having an infinite radius, and one divided by infinity is zero. If the curvature of a convex surface is considered positive, that of a concave surface is negative, and it will be easy to remember that beneath a surface of positive curvature the pressure, *p,* is more than, and beneath a surface of negative curvature less than that beneath a plane surface. (Incidentally, mathematicians will remember that a quantity changes its sign in passing through zero or infinity.) Plainly, this difference of pressure increases with the curvature, as may be experimentally proved by the behavior of a drop of liquid in a tube of small but varying diameter. If

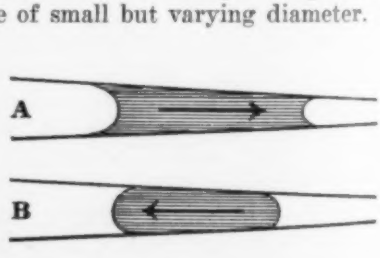


FIG. 12. DROPS AND BUBBLES.

the liquid wets the tube, the drop will assume the shape shown in Fig. 12A, and move toward the right, *i.e.*, towards the end which has the greater negative curvature, where p is less. If it does not wet the tube, the drop assumes the shape shown in Fig. 12B, and moves toward the left. If, however, we have a bubble of air in a tube filled otherwise with liquid which wets the tube, the bubble moves to the left (12C), and the greater the difference between the curvatures at the ends of the bubble, the greater this tendency to move. (Compare this condition with two capillary tubes of different diameters. The tendency of the liquid to rise in the tube is greater the smaller the tube.) If you try to blow out the air and water from a tube ending in a capillary, you will find it almost impossible, owing to this opposing force.

This has an application that is of the greatest importance to caisson workers. At the great pressure to which they are subjected, an unusual amount of air is dissolved in the blood, the amount being proportional to the pressure. When they come out from this pressure, the blood can no longer hold the gas in solution, and it appears in tiny bubbles in the blood stream. Bottled pop acts similarly when the stopper is removed from the bottle. These bubbles obstruct the flow of blood through the capillaries, and we have the condition illustrated in Fig. 12C. This causes cramps in the muscles known as the "bends." One would think that any tube that would pass blood would also pass air, and so it would be if the tube were filled with air alone. But as a bubble approaches the narrowing, almost microscopic part of the capillary, the pressure behind the smaller end becomes greater than the driving force of the heart.

Surface Tension and Electric Charge

A useful application of this principle has been found in a device for making and breaking an electric current. A small glass tube ending in a capillary is filled with mercury and connected with one pole of a source of electricity, as in Fig. 13. The other pole is connected to

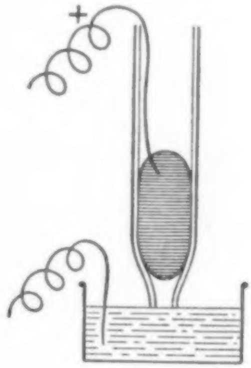


Fig. 13. Capillarity electrical interrupter.

a vessel of sulfuric acid, placed beneath the vertical tube. As soon as the convex surface of the mercury becomes charged, the self-repellent action of the charge on the surface partially neutralizes the surface tension of the mercury. The mercury drops down the tube, therefore. But the instant it comes in contact with the sulfuric acid, the latter is electrolyzed; gas is formed which breaks the electrical connections; and the surface tension of the mercury draws it back into the tube where it again accumulates an electric charge.

This action of an electric charge in diminishing the surface tension of a

Fig. 14. A jet of water breaks up into drops because of surface tension.

drop may be shown in a very pretty manner by bringing a charged rod near a jet of water. Ordinarily a small jet

breaks up into drops, owing to the surface tension acting on the column of water. But when these drops are

FIG. 15. A CHARGE OF ELECTRICITY ON A JET OF WATER, BECAUSE OF ITS SELF-REPELLANT ACTION, NEUTRALIZES THE CONTRACTILE ACTION OF SURFACE TENSION.

charged by induction from the rod, the surface tension is so neutralized by the presence of the self-repellent charges that the drops run together again to form a solid column—rather, the column does not break up.

SURFACE TENSION AND EVAPORATION

It is not necessary that the capillary tube be dipping into water to show the difference of level discussed on page 153. For if a capillary (Fig. 16) sealed at its lower end be supported in the same way, and the entire system then placed beneath a bell-jar, the water will distil over from the flat surface and condense on the concave surface within the tube, until the difference of level is the same as before. This seems puzzling until we remember the condition of a molecule of water vapor above the surface at less than the diameter of the sphere of influence. The molecule M within the closed tube is pulled equally in all directions except downwards by the other molecules of vapor inside the sphere of influence, represented by the circle. The downward force is greater because of the greater number of molecules per volume below the surface of the liquid, and this downward attraction is evidently greater below the curved surface than below a flat surface by the attraction of the molecules within the volumes ACES. Remembering that a constant interchange is going on between the

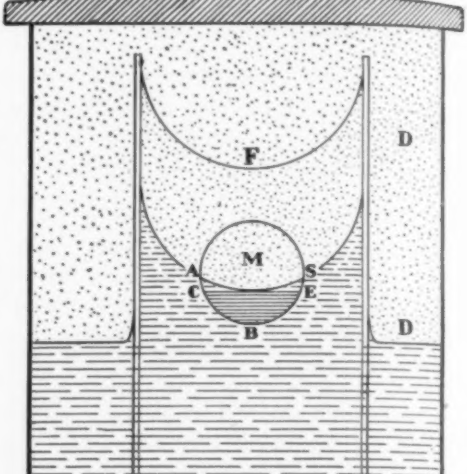


FIG. 16. LIQUID DISTILLING OVER FROM A FLAT TO A CONCAVE SURFACE.

liquid and vaporous conditions, it is plain that more molecules will enter the concave surface and that this must go on until the level within the tube has reached a height, say at F, where the diminished number of molecules per cubic centimeter (remember the rarefied air on the mountain top) just balances this greater tendency to pass below the concave surface, since the evaporation is more rapid into a region with fewer molecules. Of course the opposite condition prevails beneath a convex surface, and we might sum up by the statement that the vapor pressure, which measures the tendency for a molecule to pass through the surface or condense, is greater immediately above a concave, less above a convex surface. Compare this with the previous discussion of the pressure beneath the surface, and re-

member that difference increases with the increase of curvature.

Let us follow this a little further. Suppose the convex surfaces are on two drops of different sizes in a saturated vapor. There will be a greater tendency for the vapor to condense on the larger drop than on the smaller, consequently there will be a tendency for the larger drops to grow at the expense of the smaller The smaller the drop, the less the tendency for the vapor to condense, so that by the time we get down to molecular dimensions, there is, theoretically, no tendency at all, and in a region with no drops, the space may become supersaturated with vapor, with no tendency toward the formation of drops, although the liquid may condense slowly on the walls The situation is entirely changed, however, if there are nuclei present, such as dust particles, to furnish the curved surfaces. Then condensation occurs, and we have a cloud of drops, each with a particle of dust at the center. This is the explanation of the prevalence of fogs in the city, where there is an abundance of smoke and dust particles to serve as centers of condensation. London, with its millions of tons of soft coal burned every year, much of it in open grates with their incomplete combustion, is the best example of this. They should adopt the slogan, "Less smoke, less fog." This is not to say that no smoke (or dust) would mean no fog, for ionized particles or molecules will serve as centers of condensation, and when the saturation reaches a sufficiently high point, drops will form anyway. It is possible that the "cloudbursts" which often occur in the mountainous regions of the west, where the air may reasonably be expected to be freer of dust than air near large cities, are to be explained by the presence of a very large body of highly supersaturated air. When drops do begin to form, condensation takes place (*i.e.*, drops grow) with great rapidity.

For precisely similar reasons, bubbles within a liquid are formed with great difficulty unless there are nuclei present. Here we have a surface that is concave towards the vapor, and the tendency for molecules to pass from the liquid to the vaporous side of such a surface diminishes with the size of the bubble. In vessels quite smooth on the inside, pure liquids may be heated far above the boiling-point before ebullition begins. But when it does begin, it is apt to proceed with explosive violence, since the growth of the bubble makes it progressively easier for evaporation to occur at the surface of the bubble.

Surface Energy

Evidently, the surface of a liquid is the seat of potential energy, just as a spring which has been extended is said to possess potential energy. The amount of this energy can be calculated easily, if we remember that the definition of surface tension is that force in the surface of a liquid exerted at right angles to a line one centimeter long. If we imagine ourselves stretching the surface by a pull at right angles to this line, we must do work. By the time we had displaced the line one centimeter, or increased the surface one square centimeter, the work would have amounted to a number of ergs equal to the value of the surface tension in dynes. When the surface contracts, work is done by the surface, and the total "available" energy is that given by contracting to the smallest area, *viz.*, a sphere, plus the amount of heat that has entered the liquid from the outside. In the case of water, at zero centigrade, this amounts to 117.3 ergs per square centimeter.[1] As stated before, the presence of impurities may increase or decrease this amount. Whenever the potential energy of a system becomes less, kinetic energy becomes available for doing ex-

[1] Edser's "Physics," p. 295.

ternal work. Thus a watery solution may *do work* either by diminishing its total surface, or by a change in the chemical constitution of its dissolved material in such a way that the resulting mixture has a smaller surface tension. There have been several more or less successful efforts to explain the mystery of muscular contraction by changes in the surface tension within the muscle fibers.[2] Certain it is that, although heat is involved in the performance of work by muscles, it is a by-product, and by no means the intermediary by which chemical energy is transformed into mechanical energy. Reasons for this belief cannot be given here.

Loeb's famous work on the fertilization of the egg of the sea-urchin showed that the changes that took place were accompanied by changes in the surface tension of the egg. When these changes in surface tension were produced by changes in the chemical constitution of the medium in which the egg was immersed, cell division (development) proceeded for a time quite as if the cell had been fertilized in the regular way.

Every high-school pupil has heard of the law of conservation of energy, sometimes spoken of as the first law of thermodynamics to remind us that heat energy comes under the same generalization. But the second law of thermodynamics is of equal importance to those trying to *use* energy. It refers to "the running down" of energy and is the death-blow to every scheme of perpetual motion. To give a few examples: A wound-up clock has a certain amount of potential energy; as it runs down, this potential energy becomes kinetic energy (it moves the hands; it strikes the chimes; it might keep a lot of mannikins in motion) and a *part of this is dissipated as heat, never to be recovered.* We shall never have a clock that is able to wind itself up quite as tight as when it started. Part of the potential energy of the water above the falls is dissipated into heat as it passes through the motors. The compressed gas or steam expands; again potential energy is converted to kinetic energy with the loss of a fraction in dissipated heat. In all the experience of mankind for thousands of years, nothing has happened to controvert this statement of the second law: *The potential energy of the universe tends to a minimum.* We have seen how this is illustrated in the case of surface tension by a shrinkage of the surface. But we can carry this a little further. If the liquid has dissolved in it something that *lowers* the surface tension, it will be lowered more, that is, the potential energy will be further diminished, by a concentration of the dissolved material in the denser layer that forms the boundary between the solution and the surrounding medium. Albumen in water is such a substance. The amoeba is said to be a blob of "protoplasm with no cell-wall," *i.e.*, no wall that will take a stain and so be differentiated under the microscope. But if there is a *surface,* there is a *surface tension,* and in this case with more of the albuminoid portion in that layer, which, because of the surface tension if nothing else, must be denser than the main body of the solution. Perhaps this is the beginning of all cell walls.

We have wondered why we can blow soap bubbles and not water bubbles, even though the water has a higher surface tension than soap solution. Just because the soap solution does have a lower surface tension, it is more concentrated near the surface. Suppose now that the bubble starts to blow out, the first step in a break. The first thing to happen would be a thinning of the layer of soap at that spot, with a strengthening of the surface as it became more watery and less soapy, and the bulge would be im-

[2] Howell's "Physiology," p. 75.

mediately pulled back. So the entire sphere, though weak, is under the sway of perfectly balanced forces, and hence stable.

A film of oil on the surface of a stormy sea has the same effect on small waves. Under ordinary conditions, wherever a wavelet sticks up, the wind catches it, beats it back with emphasis which produces a bigger wave, and so on until waves are "mountain high." But if the first little wave has to push through a film of oil with a smaller surface tension, it is treated like the first bulge on the surface of the soap bubble—it is immediately pushed back into shape before the wind catches it. The huge breaking waves, so dangerous to shipping, are transformed into long, smooth rollers which even small boats may ride safely.

Speaking of the dangers of the great deep reminds us that, if you ever are shipwrecked, you don't need to go without fresh water. Remember that since salt *increases* the surface tension of water, the rule we have just been discussing shows that if potential energy is to be a minimum, the salt must draw back from the surface, leaving a film of fresh water spread over every body of salt water, so all you need is patience and a sufficiently delicate skimmer to get all the fresh water you want.

And here we may as well stop, not because the subject is exhausted, but probably the reader's patience is.

SCIENCE SERVICE RADIO TALKS

PRESENTED OVER THE COLUMBIA BROADCASTING SYSTEM

HEAVY-WEIGHT HYDROGEN

By Professor HAROLD C. UREY
DEPARTMENT OF CHEMISTRY, COLUMBIA UNIVERSITY

I HAVE been asked to talk to you this afternoon on the subject of "Heavy-weight Hydrogen," which Dr. Brickwedde, Dr. Murphy and I discovered about a year and a half ago, and which at the present time is proving to be a very interesting substance in the sciences of chemistry and physics. In fact, some five or six university laboratories in the United States are very actively engaged in investigating the properties of this substance, and its commercial manufacture has been undertaken by at least one company and is well under way. In order to tell you something of the interest which physicists and chemists have in this hydrogen, it is necessary to tell you how it fits into a broad development of these sciences which began over a hundred years ago, and which is more interesting to-day than it has been at any time in the past.

But before doing so, I must tell you a little about the differences between this new form of hydrogen and the previously known variety, and give you the names of the two varieties.

The previously known variety of hydrogen has been referred to among scientists as "hydrogen one," while the heavy-weight hydrogen has been known as "hydrogen two." The "one" and "two" refer to the weights, or more correctly, the masses of the single atoms of the two varieties, the one having a mass of 1/16 the mass of the oxygen atom, and the other 2/16 of the mass of this atom. Thus, if the oxygen atom is assumed to have a mass of 16, these two varieties of hydrogen have masses of 1 and 2, respectively, and hence the names. Recently we have proposed the names protium and deuterium from the Greek words meaning first and second, for these varieties, but in this talk, I shall use mostly the names hydrogen one and hydrogen two. With this brief statement, let me return to the historical story of atoms as it bears on the story of hydrogen two.

Among the great variety of material substances which we observe about us, there are about ninety which we call elements. These are substances which we can not break up by chemical means into simpler substances. In 1803 John Dalton suggested that all matter consisted of very small particles which he called atoms. All the atoms of an element were assumed to be precisely alike as to size, weight and chemical behavior. Chemists early discovered methods for determining the relative weights of these atoms and Prout, in 1815, pointed out that the weights of these atoms appeared to be multiples of that of the hydrogen atom. He made the hypothesis that the atoms of the elements were made up of closely packed hydrogen atoms. Elements were found which contradicted this hypothesis, and it had to be abandoned toward the end of the nineteenth century. It has been revived recently, and this hypothesis that the elements are all composed of the element hydrogen one is of interest to-day in connection with the rare hydrogen two.

We now turn to another interesting

chapter of this subject. During the closing years of the nineteenth century, the phenomena of radioactivity were discovered, and it was found that there are a very considerable number of elements which are spontaneously changing, one into another. As a result of the study of these transformations of certain elements into others, it was found that some of these radioactive elements have exactly similar chemical properties, but that the weights of the atoms are not identical and the radioactive characteristics are different. Thus radium and mesothorium 1 can not be separated chemically, but radium requires about 1,800 years for one half of it to change into another element, while mesothorium 1 requires only seven years to make a similar amount of change. Also their atomic weights are 226 and 228, respectively. Such atoms, having similar chemical characteristics but different atomic weights, are called isotopes. Many examples of this kind were found among these radioactive elements. The next step in the development of our subject was made when it was shown that ordinary elements, such as neon, familiar to us all in the neon signs, chlorine, one of the constituents of table salt, and many others, consisted of mixtures of atoms having very similar chemical properties, but differing in their weights. In recent years, Aston in England has investigated the composition of a great many of our elements, and found them in the majority of cases to be mixtures of such isotopes. Recently, investigators in this country have found that such ordinary elements as oxygen, nitrogen and carbon also consist of such mixtures. These individual isotopes were found to have atomic weights which are very nearly whole numbers, so that we feel certain that Prout's hypothesis is at least partially true when applied to the individual isotopes and that the atoms of the elements are probably composed of a whole number of hydrogen one atoms.

This situation was well recognized two years ago, and hence we hoped to find an atom of atomic weight two, for it would consist of only two hydrogen one atoms and be the simplest of these complex atoms.

Professor Birge, of the University of California, and Dr. Menzel, of the Harvard Observatory, gave reasons for believing that hydrogen two might be present to the extent of one part in 4,500 of the hydrogen one variety. An isotope as rare as this had never been detected, and thus it was necessary to concentrate the isotope. This was done by Dr. Brickwedde at the Bureau of Standards at Washington by distilling liquid hydrogen at −466 degrees Fahrenheit. In this way, the concentration of hydrogen two was increased to one part in 1,100, which enabled Mr. Murphy and myself to prove its existence by means of its spectrum. Since then Dr. Washburn, of the Bureau of Standards, has found that the hydrogen two can be concentrated by the electrolysis of solutions of caustic potash. This method has been used by a number of investigators to prepare samples of hydrogen containing high concentrations of the hydrogen two. In fact, Professor Lewis, of the University of California, has secured a small sample containing 99.5 per cent. of this new hydrogen, or deuterium, as we have agreed to call it. In the next few years deuterium, this new form of hydrogen, is destined to be the subject of much serious work, both in chemistry and physics, and I think it may interest you if I say something of these possible developments.

In recent years we have come to understand the structure of atoms much more thoroughly, and we find that an atom consists essentially of two parts. First, there is the central sun of a miniature solar system, which carries a positive charge of electricity. Moving about this in some way which we can not quite visualize, but which must be some-

what like the planets of the solar system, are a considerable number of negatively charged electrons. Once we have fixed the number of electrons of any atom, the chemical characteristics are determined. Thus, if there is one electron to each atom, the element is hydrogen; if two, the element is helium; if three, lithium; if four, beryllium; if five, boron; if six, carbon; if seven, nitrogen; if eight, oxygen; if ninety-two, uranium, with all the other elements lying between. However, the mass of the atom is carried by the central sun of nucleus of the atom, and thus this weight is determined by the number of particles that there are in the nucleus of the atom. The nucleus of the hydrogen atom of atomic weight 1, or protium, consists of but a single particle which we call the proton. The hydrogen atom of atomic weight 2, or deuterium, has a nucleus which consists of one proton and one neutron, the latter being a particle having a weight about equal to the weight of the proton but carrying no charge. Thus the nucleus of a hydrogen atom having an atomic weight 2 would be the next to the simplest nucleus to be found in all our atoms. If we are to understand the structure of the central suns of our atoms, it is obvious that we must try to find the simplest and then the next simplest, and the third simplest, etc., of these bodies, for by understanding them we are able to go on to the more complicated types. An important beginning in this direction has been made already in the study of reactions involving these central suns of protium and deuterium and other atoms. Thus lithium of atomic weight seven and protium react to form helium, and also deuterium and lithium of atomic weight six change into helium. These reactions give out enormous quantities of energy, about one million times the energy of ordinary chemical reactions. Moreover, this deuterium nucleus is probably the only one which can be described by an exact theory, and this theory will certainly be forthcoming in the next few years. These are the principal interests of this atom to physics.

On the chemical side, a few indications of rather marked differences in the behavior of protium and deuterium are known. We are very much interested in knowing why the chemical elements behave the way they do. How does hydrogen gas burn? How do chemical reactions take place in our bodies? And many others. We know that the answers to these questions involve many factors, but one that runs through all our considerations is the effect of the weight or mass of the atoms. In the case of all the elements except hydrogen, the mass of the atoms makes such small differences in chemical behavior that they can not be measured, while in the case of protium and deuterium, the differences are easily detected. For example, waters made from these two isotopes differ in melting point and boiling point. Also, reactions involving the two isotopes must proceed with markedly different velocities. I shall be surprised if the biological effects are not interesting. Perhaps mice containing deuterium instead of protium in their bodies may move very slowly or perhaps not be able to live at all, so that the new hydrogen may be a poison. Like all new scientific toys, we do not know what tricks it will do until we have played with it a while, and—who knows?—it may turn out to be useful to all of us as well as entertaining to scientists.

GARDENS OF TREES

By Dr. RODNEY H. TRUE

DIRECTOR, MORRIS ARBORETUM OF THE UNIVERSITY OF PENNSYLVANIA

FROM what we can learn from history, the first garden consisted of a garden of trees. It seems likely that these trees were cultivated date palms. The question with us immediately arises as to what characteristic quality makes a garden. To most of us the word usually suggests small plants, perhaps predominantly herbs, that are cultivated in designs of more or less elaborate nature. Perhaps gardens were once mainly trees, bearers of fruit. However that may be, date palms, olives and pomegranates have always had a prominent part in garden plantings in the older lands with milder climates.

In these later days, gardens of trees and shrubs have become arboreta, and the old gardens of cultivated fruit trees have become orchards to English-speaking peoples. In European lands, botanic gardens have been long known as usual city institutions, and few of the larger cities of Europe lack a botanic garden. These gardens are usually composite plantings in which a variety of trees, shrubs and herbs are to be found selected and arranged for the purpose of instruction and often for esthetic enjoyment.

In the New World, still fresh from the struggle between the natural forests and the demands of agriculture, the planting of trees at first consisted largely of fruit orchards. Now, however, the forest has disappeared, the production of food has claimed an area beyond the requirements of the situation and the tree for itself is becoming an object of increasing interest. Gardens of trees are being established as a part of the equipment of a land rapidly becoming one of cities. Gardens and arboreta connected with municipalities or with institutions of learning are apparently an indication of the growing age of our country and of a recognition of the fact that in the passing of forests we are in danger of losing not only our source of lumber, but also something else fully as real as timber, even though less tangible. Why, then, are public-spirited citizens, educational institutions and, in cases, municipalities, planting and fostering gardens of trees?

We may all agree, I believe, that trees, especially big trees, make a very deep appeal to the souls of men. Their great dimensions, their beauty of form and color, their long life that in duration makes us creatures of but a few seasons —all inspire in us a certain reverence. It is not hard for the tree lover to understand the tree worship of earlier times. We have our California giants remaining to testify of geological epochs, and most of us are gratified when we learn that groups of these citizens of the bygone centuries are being protected to continue to speak their message to generations yet unborn. Most of us in some degree worship trees, big trees, and hope that for centuries to come they may abide to tie together the feverish periods of human history. If we chance to live in cities with all their human noises, rushings-about, smells and sordidness, who can measure the value of trees, big trees, as a restorative to sanity and health of soul? And as the seasons come and go, with buds, flowers and seeds, gray bark and naked branches, we see the trees as nature's timekeepers, running in accord with the schedule of the heavens.

Trees also serve humbler purposes, connected with the affairs of daily living. When the wood is burned in the stove or fireplace, the glow of the coals and the glory of the flames warm us, cook our food and cheer our souls. As the body of the tree is built up through

the years out of carbon dioxide and water and a little mineral material from the soil, sunlight is stored. The quiet wood holds chained the mighty energies flashed across interstellar spaces to our earth—to our tree—and gives them up at our need.

That same tree body may be sawed and planed and polished and made into furniture, or it may be left unfinished to furnish frames for our houses. In the hands of artists it may become inspired carvings. Now the chemist dissolves it into a liquid from which a myriad of things are made, and wood threatens to rival coal tar as a raw material in the variety of things made from it.

Now, what has this to do with our garden of trees? Indirectly very much, perhaps. America has awakened almost with a start to the fact that the passing of our forests has left us heirs to a host of problems. Metals and concrete more and more are being used as substitutes for wood in construction work. Most of us have long since unwillingly ceased to use wood as a fuel. But we still feel compelled to restore the forests, and a campaign of reforestation of increasing vigor is developing. Trees are needed to protect the soil against the never-ending work of water. Erosion has already ruined vast areas of land and, by filling the streams and by choking up the channels of rivers with transported silt, forms the basis for disastrous floods.

What trees shall be planted? Much thought must go before a wise answer. Trees must be planted that will thrive in the soil and climate of our proposed forest. The sorts planted must be free from our own native diseases and from imported ones, or they must be able successfully to resist them now and for the decades to come. The trees to be planted should not only grow well, keep healthy and fit the climatic and soil conditions of regions in which they are supposed to live, but they must be able to hold the soil in place and in the end to yield an acceptable trunk when the killing time comes.

We can not rely too confidently on our native sorts. What about the chestnut? What about the white pine now suffering from the blister rust? What about other known or obscure diseases and insects that are eating our forest trees? What have other parts of the world to offer? May some Old World trees prove valuable? Here a garden of trees becomes of practical value. A collection of many sorts from many sources is likely to offer a wealth of information. Here the habit of growth, soil requirements, susceptibility to disease, methods of reproduction and a host of other characteristics may be studied. The careful, scientific records of an arboretum yield many kinds of valuable information. Materials for anatomical study, the story of the life history, none too accurately known for most of our trees, taxonomic relationships and the basis of a host of other scientific investigations will be found in an arboretum, and the greater the variety of trees and shrubs present, the wider will be the range of possibilities.

Not the least important use of such a collection will be that offered to the horticulturist and to the landscape architect. In such a collection will be found the living materials which the artist will have at his disposal in working out his designs. Here the opportunity to see and study at different seasons the appearance and behavior of plants will be most important. Here the raw materials are displayed that, used in combinations in parks and private grounds, will yield scenes of great beauty when used by the true artist.

The establishment of a new garden of trees is a sufficient cause for real and general satisfaction, and I wish in a few closing words to speak of the Morris Arboretum of the University of Pennsylvania. Mr. John T. Morris and later his sister, Miss Lydia T. Morris, members of an old Philadelphia family, for

several decades planted trees and shrubs on the acres of their country home in Chestnut Hill on the edge of Philadelphia. They traveled extensively and found special interest in the woody plants of Eastern Asia. They participated in the results of exploring expeditions to Eastern China and to other regions of that continent, and in time built up one of the richest collections of trees and shrubs in America. On her death, Miss Morris, who survived her brother, provided for the establishment of an institution to be known as the Morris Foundation, that was charged jointly with the University of Pennsylvania with the responsibility for maintaining the collected trees and shrubs under the name of the Morris Arboretum of the University of Pennsyvlania. Funds were provided for the maintenance of the arboretum, for developing and carrying on a graduate school of botany in which research in plant science should be provided for, for the publication of these results and such other material as should be decided on, for the hiring of eminent scientists to deliver lectures, for providing fellowships for advanced students and for scholarships for boys and girls studying horticulture and related subjects, for carrying on scientific studies and explorations both in our own and in foreign lands, and for the distribution of plants to the interested public. A staff of workers has been appointed and participation in explorations in China and Thibet have been provided for.

Thus, the resources of the new garden of trees will not only provide for a further development of the beauty for which the Morris home has long been known, but will serve in a distinctive way to advance scientific knowledge.

POISON IVY AND POISON SUMAC

By L. E. WARREN

FOOD AND DRUG ADMINISTRATION, U. S. DEPARTMENT OF AGRICULTURE

There are numerous plants which, when touched by human beings, may cause irritation to the skin. Most of these, like the iris, lady slipper, oleander, flax and squill, are so nearly inert during most of the season that severe poisoning from contact with them occurs but rarely. However, there are two, poison ivy and poison sumac, which may never be handled without danger. Of these poison ivy is much the more common and, consequently, poisoning from it is much more frequent. Undoubtedly many persons, particularly children, are poisoned because they do not know how to recognize and avoid these plants. There are probably no other plants about which so much misinformation has been disseminated, or is current in the general beliefs concerning them. The nature of their poison, its methods of transmission from plant to person, how it produces its toxic effects and the treatment of the skin inflammation which it causes have been the theme of countless myths, miraculous stories and fanciful theories for more than three hundred years. Even to-day, after numerous profound researches, there are several phases of the poison ivy problem which are far from being well understood.

What is Ivy Poisoning?

Ivy poisoning is a peculiar inflammation of the skin caused by coming in contact with poison ivy. Sumac poisoning is analogous. The symptoms range from slight redness and itching to enormous swelling with extensive blisters, accompanied by severe burning sensa-

tions. There are all gradations between these extremes. In mild cases the skin is covered with numerous small blisters. The blisters contain a colorless serum which is not poisonous; consequently poisoning can not spread from broken blisters. Pustules may form and infections may result as secondary consequences. The disease tends to recover in from ten days to three weeks. Occasionally, a persistent dermatitis follows.

Poison ivy is known by various names in different parts of the country, such as poison ivy, poison oak, poison vine, three-leafed ivy and poison creeper. The plant is found in practically every part of the continental United States, high mountains and deserts excepted. Botanists find some variations in the forms occurring in the various sections of the country. Although these differences are sufficiently great to constitute several distinct species, the general appearance of the plants and their habits of growth are so much alike that if one form is known the others usually may be recognized. Poison ivy has been known in America from the time of the early settlements. Thus, as early as 1609, more than a quarter of a century before any botanist had described the plant, Captain John Smith described the symptoms caused by touching it. He writes:

> The poisonous weed, being in shape but little different from our English yvie; but being touched causeth reddness, itchinge, and lastly blysters, the which howsoever, after a while they passe awaye of themselves without further harme; yet because for the time they are somewhat painefull, and in aspect dangerous, it hath gotten itselfe an ill name, although questionlesse of noe very ill nature.

Poison ivy adapts itself to almost every kind of soil, although it does not flourish in areas of scanty rainfall or at elevations of more than about 5,000 feet. It grows along hedgerows and fences, frequents woods and thickets, scrambles over rocks and climbs trees to considerable heights. Its habit of growth in thick shrubbery and hedges in such a way as to escape notice makes it especially dangerous to the unwary.

Poison ivy may be best recognized by its leaves and by its fruits. Each leaf is divided into three leaflets (never five, as in the Virginia creeper). The margins of the leaflets vary from smooth to more or less notched. The small greenish flowers appear in May and June, the male and the female flowers being borne on separate plants. The fruits, which are of the size of a small pea, are pale green and poisonous when immature, but ivory-white and not poisonous after ripening. The ripe fruits are filled with fat and are eaten by crows, woodpeckers and other birds. After the plants are a year or two old they develop aerial rootlets along the stems. These assist the plant in climbing. They also serve as an aid in identification. In the fall the leaves become brilliantly colored, principally scarlet and orange—a circumstance which victimizes many an unsuspecting collector. On being wounded the stems exude a cream-colored juice which becomes black on exposure to the air. The juice is thin and watery in the spring, but becomes thicker as the season advances. The poisonous constituent is found in this juice.

Poison sumac is also known as poison ash, poison dogwood, poison elder, poison tree, poison wood and thunderwood. It grows in swamps throughout the eastern half of the United States. It attains a height of from 5 to 20 feet and a trunk diameter of 4 to 10 inches. The bark of the shrub is light gray in color. The leaves are compound and are from 7 to 14 inches in length, each bearing from 7 to 13 leaflets. In autumn they take on wonderfully beautiful colors, brilliant reds, oranges and yellows predominating. In fact, no other plant common to the eastern United States has such gorgeously colored leaves at this season. In

the latitude of the Great Lakes these begin to color about the first of September, or a little earlier, and reach their most intense hues about October first. Many cases of poisoning have occurred in persons who have collected the autumn leaves for household decorations without recognizing their venomous nature. The fruit is a globular drupe of the size of a small pea and ivory-white when ripe. It is borne on long graceful racemes and hangs on the plant all winter unless sooner eaten by birds. It consists of a paper-like shell containing a mass of hard white fat, which incloses the seed. This is a hard, fluted stone about the size of a mustard seed. Crows and some other birds are fond of the ripe fruits. They digest the fat and discard the stones. The plants are disseminated by this means.

When wounded poison sumac exudes a thick juice of the color and consistency of cream, which is very poisonous. On exposure to the air the juice is converted into an almost indestructible black varnish, which is not poisonous. The early colonists in America used the juice for marking linen. In Japan the juice from a closely related species of sumac, *R. vernicifera*, has been used as a varnish for more than 20 centuries, under the name of "Japanese laquer."

Many theories to account for ivy and sumac poisoning have been advanced. The earliest explanation offered was that the plants gave off an invisible, odorless vapor or emanation which, when breathed or permitted to touch the skin, brought about the inflammatory symptoms in some unexplained way. The North American Indians had this belief in pre-Columbian days, and it is probable that the early American settlers obtained it from them. At one time it was supposed that this gas or emanation came from the plant only at night or on cloudy days. Although there has never been a particle of scientific evidence in support of this vague and irrational explanation many intelligent people still adhere to it. About 75 years ago the theory was advanced that the poisonous constituent of poison ivy was a volatile alkaloid; later that it was a volatile acid. It was supposed at one time that poisoning could take place by passing near the plants without direct contact with them. It was thought to be particularly dangerous to pass on the leeward side in such a manner that the volatile poison would be blown upon the victim. Still later the poisoning was thought to be due to bacteria.

The earliest writers associated ivy poisoning with the fabulous stories related about the upas tree of Java. According to the accounts of the early travelers the vapors from the upas tree were so deadly that persons walking under its limbs were killed almost instantly; also birds alighting in its branches fell dead. It is now known that the tales told of the upas tree were wild exaggerations and that poison ivy and this tree have nothing whatever in common.

In 1895 Dr. Franz Pfaff, of the Harvard Medical School, proved by a series of carefully controlled experiments that the poison of poison ivy was neither a gas, an alkaloid nor a volatile acid, but that it was a liquid, non-volatile substance having some of the properties of resins. It was so very poisonous that 1/60,000 of a grain of it, when dissolved in olive oil and rubbed on the skin, caused mild poisoning. Larger doses when given to rabbits by the stomach, caused death from inflammation of the kidneys, that is, Bright's disease.

The poisonous principle is found in the cell sap, in the green leaves and in the green fruits. It is not found in the pollen, or in the plant hairs which occur on the leaves and growing stems. Also the ripe leaves do not contain much of it. The poisonous principle of poison ivy is probably identical with that of

poison sumac. In the purest form so far obtained it is a dark, brownish-red liquid, resembling thick maple syrup in viscosity and general appearance. It is insoluble in water but soluble in gasoline, alcohol and melted fats. The chemical nature of this substance is not completely understood, but it has some of the properties of resins and phenols, that is, it has some of the characteristics of common rosin and of carbolic acid. Probably it is a distinct vegetable principle, just as sugar, citric acid and quinine are proximate principles of plants. The poisonous principle of poison ivy and poison sumac has been named "toxicodendrol," that of poison oak "lobinol," and that of the Japanese sumac "urushiol."

How Poisoning Takes Place

The poison of these plants not being volatile, the only way that one may be poisoned by them is to come into direct contact with the poison. This may result from touching the plants or from coming in contact with clothing, shoes, tools, and the like, which themselves have been contaminated with the sticky juice. The poison retains its virulence for a great length of time, so that if contaminated clothing or tools be laid aside at the close of the season poisoning may result the next season on their use being resumed. There are authenticated accounts of sportsmen, gardeners and workmen being poisoned after resuming clothing or shoes which had been contaminated many months before but which had been unworn in the interim. This probably accounts for most of the stories of poisoning which are claimed to have resulted by passing the plant without touching it. Smoke from the burning plants may carry minute particles of the poison. If this touches the skin or is breathed poisoning will result. Eating the leaves of the plants (as is sometimes done in the hope of producing immunity) will result in poisoning if appreciable quantities be ingested. Smearing the juices of the plants on the body (for the production of immunity) has resulted in several very severe cases of poisoning.

Does Ivy Poisoning Ever Cause Death?

The question whether ivy poisoning ever causes death is unsettled. Instances are known where death has occurred during a severe attack of ivy poisoning, but these were under conditions such that the existence of previous kidney disease could not be ruled out. It is conceivable that a person with Bright's disease in an advanced stage might be severely poisoned and that the combination of the two diseases might prove disastrous, whereas neither alone would have been fatal immediately. At any rate, fatalities from ivy poisoning are rare.

Immunity

The question is often raised whether or not certain individuals naturally may be immune to ivy poisoning. Many people claim that they have worked frequently in and around poison ivy or poison sumac and have never been poisoned. They assume this to be proof of immunity. Also there are pharmaceutical preparations made from ivy or sumac which, when taken by intramuscular injection in small doses, are designed to render individuals partially immune to the poison. McNair has investigated the subject, and he believes that immunity, or at least greatly lessened susceptibility, is possible. In the opinion of the speaker, also based upon considerable study, it seems very doubtful whether there are any persons who are naturally immune to the poison. The speaker has met several of these self-styled immunes but has found only one who was willing to submit to laboratory tests with the purified poison on the skin of the arm. This person was not immune.

How to Avoid Poisoning by Poison Ivy, Oak or Sumac

Naturally, the first requirement to avoid poisoning is to be able to recognize the poisonous plants at sight. The next is to avoid touching the plants or allowing the clothing to come in contact with them. Avoid using clothing or tools which have previously been contaminated with the juices of the plant until after they have been thoroughly scrubbed with soap-suds. If a person has touched the poisonous plants or has reason to suspect that he has, he should wash the hands or other exposed parts of the body with coal oil, rubbing alcohol or gasoline, avoiding the ethyl type of the latter and having due regard to the fire hazard. Afterward the parts should be thoroughly washed with strong soap-suds, using a flesh brush and nail file. In the absence of gasoline or denatured alcohol the washing should be done with soap-suds alone. Avoid the use of cold creams or ointments of any kind, as these dissolve the poison and tend to cause its spread by contaminating the clothing. Unless one is able to identify these plants positively, the collection of brightly colored autumn foliage from climbing plants or those having aerial rootlets or from swamp shrubs should be avoided. Also while on outings, wild berry pickings or hunting, contacts with thickets and tangled brushwood should be avoided as much as possible.

Treatment of Poisoning

Much has been written about the treatment for ivy poisoning and many remedies recommended as "sure cures." Almost every drug in the materia medica has been proposed at one time or another. Probably the reason for this multiplicity of suggested remedies lies in the fact that ivy poisoning is a self-limited disease, that is, it tends to get well of itself without treatment of any kind. Sufferers from the disease, because of the intolerable itching and other discomforts, will try any remedy suggested by their friends. After trying one for a day or two and procuring no relief or but little they will try another, then another and so on until Mother Nature effects a cure. The last remedy tried is the one which gets the credit for the cure.

Among the remedies which have been recommended by a considerable number of physicians are aqueous solutions of sodium sulphite, dextrose, magnesium sulphate (Epsom salt), picric acid, permanganate of potash and 5 per cent. iron chloride in 50 per cent. alcohol. McNair recommends that after the application of one of these solutions, preferably the iron chloride, the surface be dried and melted paraffin applied as a spray with an atomizer. A thin layer of absorbent cotton is then laid on, followed by another layer of melted paraffin. This dressing is to be changed daily.

During the past few years extracts made from ivy or sumac have been given in the treatment of ivy or sumac poisoning. They are administered chiefly by intramuscular injections. Their introduction is too recent to determine whether they will have a permanent place in therapy. After all, in ivy poisoning, more than in almost any other disease, an ounce of prevention is worth many pounds of cure.

WORK OF THE NATIONAL BUREAU OF STANDARDS ON INDUSTRIAL MATERIALS

By P. H. BATES

CHIEF, DIVISION OF CLAY AND SILICATE PRODUCTS, NATIONAL BUREAU OF STANDARDS

In an era such as that in which we are now living, it is rather difficult to define an industrial material. Yesterday a material or a product may have been made for the first time in the laboratory and may have been considered a matter of laboratory interest at the moment; to-day it is noted that it might have a practical use in some industry; to-morrow it will be a necessity in many industrial applications. Hence, in the broadest sense of the term, a presentation of the Bureau of Standards' work in "industrial materials" would include essentially all its activities. As very many of these have already been covered in this series, this article will be limited largely to some materials of recognized industrial importance.

However, first there will be cited the Bureau's work on an industrial material—steam—which generally would hardly be classed as such. But in many localities it is being distributed from central plants to rather distant points of application. Further, it is a material used in the conversion of the latent energy of certain materials into a more readily distributed form. For several years the Bureau of Standards has been handling, in cooperation with several other laboratories both here and abroad, a comprehensive program for the establishment of accurate and uniform tables of the thermodynamic properties of steam. The work concerns the direct measurement of latent and specific heats of water over the entire useful range from the freezing point to the critical point, and the specific heat of superheated steam at high temperatures. This program has been completed in the range 0° to 270° C. and the remainder, covering the higher temperatures, is nearing completion, except for the heat capacity of superheated steam, which will require different experimental equipment.

The dependence of the world and of the United States in particular on gasoline as a source of power is such a new development that its importance is seldom fully realized. The qualities of this product have varied widely with variations in the available supply and in the current demand. The importance of the solution of the broad economic problem of efficient use of petroleum resources was recognized some ten years ago by the automotive and petroleum industries, and a cooperative research project was established at the Bureau of Standards to meet the need. As a result, from simple laboratory tests of a gasoline one can predict the minimum temperature at which an engine can be started and the maximum air temperatures at which it will run; the tendency to knock and the tendency to dilute the crankcase oil; how well the engine will accelerate and whether the fuel is safe from a corrosion standpoint.

An interesting case of cooperation by the Bureau with a profession, through the latter's desire for a better understanding of the materials with which it

is vitally concerned, is evidenced in the studies which are being made on dental materials. The American Dental Association has for some years borne half the expense of extensive research to determine the physical properties of products used in dentistry, such as amalgams, dental gold alloys, cements, waxes and investment compounds. As a result of these researches specifications have been prepared which embody the desirable and safe characteristics of these materials. The value of this work to the dental profession and more especially to the public, measured in terms of increased effectiveness and permanency of dental restorations, can not be expressed in dollars and cents.

The very important group of materials commonly referred to as "protective coatings," including paints, varnishes, lacquers and baked and vitreous enamels, have been extensively studied at the Bureau. The work concerns both the determinations of the nature and properties of the component materials and of the finished products, and tests which will indicate in a short time what will be the length of service. These materials are of special interest at the present time due to the marked development of synthetic resins and solvents which are offering so much competition to the formerly used oils and volatile liquids of the paint trade. Some equipment used to determine in a short time the effect of light and water upon protective films is illustrated herewith. Essentially it consists of a revolving cylinder on the inside of which such films can be placed and be subjected to the action of light from the carbon arc and of water. The fusing of siliceous enamels upon cast irons and soft steel produces a type of protective coating which is finding ever increasing uses, not only in the home but in industry. Since the procedure of manufacture of such coatings requires the melting of the enamel on the heated surface of the metal, many interesting problems arise. Among these can be mentioned the determination of the coefficient of thermal expansion of both the metal and the enamel over the range of temperatures extending from that of average room temperature to that at which enamel is produced. An equally important study is that of determining the effect of each of the ingredients of the enamel upon this coefficient.

The investigations of the vitreous enamels are somewhat similar in nature to those being carried out on glass. Originally, the Bureau became interested in studies of glass for two reasons. Its chemical laboratory needed glass resistant to the commonly used reagents and the glass industry was producing a number of purported resistant glasses. Its Optical Division was interested in a more ready source of optical glass than Europe. It was therefore decided to study the effects of the various oxides used in glass manufacture on the resultant physical properties. The work was hardly under way before the late war broke out and the military branches of the government were in dire need of the special glasses required for their optical instruments. Following the request of the Navy Department, quantity production of optical glass was started and has been continued to date. At the present time 3,000 pounds of optical glass in the form of molded slabs for various instruments are delivered annually to the Navy. While producing this, investigational work is in progress covering the relation between composition of the glass and properties such as index of refraction, dispersion, density, viscosity, thermal expansion, annealing, etc. Also, the Bureau has had the honor of producing the largest optical glass disk for an astronomical reflector ever

WORK OF THE NATIONAL BUREAU OF STANDARDS ON INDUSTRIAL MATERIALS

By P. H. BATES

CHIEF, DIVISION OF CLAY AND SILICATE PRODUCTS, NATIONAL BUREAU OF STANDARDS

In an era such as that in which we are now living, it is rather difficult to define an industrial material. Yesterday a material or a product may have been made for the first time in the laboratory and may have been considered a matter of laboratory interest at the moment; to-day it is noted that it might have a practical use in some industry; to-morrow it will be a necessity in many industrial applications. Hence, in the broadest sense of the term, a presentation of the Bureau of Standards' work in "industrial materials" would include essentially all its activities. As very many of these have already been covered in this series, this article will be limited largely to some materials of recognized industrial importance.

However, first there will be cited the Bureau's work on an industrial material—steam—which generally would hardly be classed as such. But in many localities it is being distributed from central plants to rather distant points of application. Further, it is a material used in the conversion of the latent energy of certain materials into a more readily distributed form. For several years the Bureau of Standards has been handling, in cooperation with several other laboratories both here and abroad, a comprehensive program for the establishment of accurate and uniform tables of the thermodynamic properties of steam. The work concerns the direct measurement of latent and specific heats of water over the entire useful range from the freezing point to the critical point, and the specific heat of superheated steam at high temperatures. This program has been completed in the range 0° to 270° C. and the remainder, covering the higher temperatures, is nearing completion, except for the heat capacity of superheated steam, which will require different experimental equipment.

The dependence of the world and of the United States in particular on gasoline as a source of power is such a new development that its importance is seldom fully realized. The qualities of this product have varied widely with variations in the available supply and in the current demand. The importance of the solution of the broad economic problem of efficient use of petroleum resources was recognized some ten years ago by the automotive and petroleum industries, and a cooperative research project was established at the Bureau of Standards to meet the need. As a result, from simple laboratory tests of a gasoline one can predict the minimum temperature at which an engine can be started and the maximum air temperatures at which it will run; the tendency to knock and the tendency to dilute the crankcase oil; how well the engine will accelerate and whether the fuel is safe from a corrosion standpoint.

An interesting case of cooperation by the Bureau with a profession, through the latter's desire for a better understanding of the materials with which it

is vitally concerned, is evidenced in the studies which are being made on dental materials. The American Dental Association has for some years borne half the expense of extensive research to determine the physical properties of products used in dentistry, such as amalgams, dental gold alloys, cements, waxes and investment compounds. As a result of these researches specifications have been prepared which embody the desirable and safe characteristics of these materials. The value of this work to the dental profession and more especially to the public, measured in terms of increased effectiveness and permanency of dental restorations, can not be expressed in dollars and cents.

The very important group of materials commonly referred to as "protective coatings," including paints, varnishes, lacquers and baked and vitreous enamels, have been extensively studied at the Bureau. The work concerns both the determinations of the nature and properties of the component materials and of the finished products, and tests which will indicate in a short time what will be the length of service. These materials are of special interest at the present time due to the marked development of synthetic resins and solvents which are offering so much competition to the formerly used oils and volatile liquids of the paint trade. Some equipment used to determine in a short time the effect of light and water upon protective films is illustrated herewith. Essentially it consists of a revolving cylinder on the inside of which such films can be placed and be subjected to the action of light from the carbon arc and of water. The fusing of siliceous enamels upon cast irons and soft steel produces a type of protective coating which is finding ever increasing uses, not only in the home but in industry. Since the procedure of manufacture of such coatings requires the melting of the enamel on the heated surface of the metal, many interesting problems arise. Among these can be mentioned the determination of the coefficient of thermal expansion of both the metal and the enamel over the range of temperatures extending from that of average room temperature to that at which enamel is produced. An equally important study is that of determining the effect of each of the ingredients of the enamel upon this coefficient.

The investigations of the vitreous enamels are somewhat similar in nature to those being carried out on glass. Originally, the Bureau became interested in studies of glass for two reasons. Its chemical laboratory needed glass resistant to the commonly used reagents and the glass industry was producing a number of purported resistant glasses. Its Optical Division was interested in a more ready source of optical glass than Europe. It was therefore decided to study the effects of the various oxides used in glass manufacture on the resultant physical properties. The work was hardly under way before the late war broke out and the military branches of the government were in dire need of the special glasses required for their optical instruments. Following the request of the Navy Department, quantity production of optical glass was started and has been continued to date. At the present time 3,000 pounds of optical glass in the form of molded slabs for various instruments are delivered annually to the Navy. While producing this, investigational work is in progress covering the relation between composition of the glass and properties such as index of refraction, dispersion, density, viscosity, thermal expansion, annealing, etc. Also, the Bureau has had the honor of producing the largest optical glass disk for an astronomical reflector ever

made in the United States, and thereby showing that the country need not depend upon foreign sources for any types of the highly specialized optical glasses.

It is patriotic for American industry to use American raw material, but it is not always economical. Whether or not it will pay can be ascertained only by making an all-American product and comparing it with that made of imported raw materials. Parachutes were made of silk, which is not produced in the United States. A careful study of the properties of silk parachutes resulted in a specification. Laboratory studies indicated ways of modifying the properties of cotton. Many experimental fabrics were woven in the Bureau's textile mill and compared with the specification. The help of the Navy was enlisted in making actual trials. This information was passed on to manufacturers, and now many of our parachutes are made of American cotton instead of imported silk, and cost about half as much.

Somewhat similar cases could be cited in the Bureau's work on clays. Not long ago pot, crucible, china and ball clays, such as used in the ceramic and paper industries, were almost entirely of foreign origin. Studies have shown that these foreign materials have no properties which can not be matched by those of domestic origin. As a consequence, in many cases the foreign clays have been replaced in part or totally by clay from domestic sources.

Naturally, work of the type just mentioned would necessitate the fabrication of raw materials into finished wares. This would require the use of plants for such fabrication. In order to carry out the needed research unhampered by commercial plant limitations of all kinds, there has been erected at the Bureau a small but complete pottery. This is not the only example of similar types of installations at the Bureau. There are experimental operating plants for producing, in a small commercial way, paper, cotton goods, rubber, glass, Portland and other hydraulic cements, lime, iron and nonferruginous metals, and a steel rolling mill. These plants are necessarily supplemented by equipment for testing the products both chemically and physically in a far more detailed manner than is usually done commercially. With the exception of the glass plant, however, none of the products of these plants are used for other than testing purposes and to correlate the results of service tests with laboratory tests.

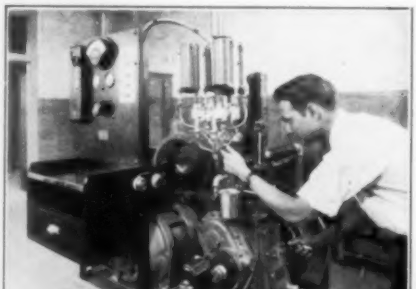
American manufacturers are constantly endeavoring to find uses for wastes. By-products are being developed, with the ultimate aim of making the tonnage of salable output from any factory approach the tonnage of raw materials used. Agriculture is now trying to follow this lead. The grain is only one half the weight of the corn plant; the other half consists of cobs, leaves and stalks, mostly the latter. There are more than 100,000,000 tons of cornstalks produced annually in the United States, and they grow in a region where lumber is relatively scarce. The Bureau has recently cooperated in perfecting a process of making boards of cornstalks, which is now in commercial use.

The query is often made as to when everything will be known about some particular material so that work on it will cease. Work on many materials has been laid aside, but not because all has been ascertained regarding it. Indeed, too frequently the more that is learned about a commodity the more information seems to be needed. Again, the demands of the industries using products are almost daily becoming more exacting and invariably because the industries

concerned have been forced to meet new demands. The construction of Hoover Dam and other large dams, for instance, has placed a new demand on concrete, namely, the evolution of less heat than commonly results when the concrete hardens as a result of the heat of hydration of the Portland cement. Two years ago there was not a laboratory in the world equipped to permit of making the determination of the heat generated during the hardening of concrete, other than a very special study after spending much time in assembling the special apparatus needed. In fact, there were only approximate data available on what the heat of hydration of cement would be and its relation to its composition, fineness, degree of burning, etc. Necessity resulting from the conditions of using cement in such huge structures has very recently caused a great amount of study in a field in which it had been assumed there was no interest, and consequently the specifications for cement for Hoover Dam will undoubtedly contain requirements limiting the heat of hydration. It appears now as though for many uses precise and accurate calorimetric work will become a matter of routine cement testing, although now

THE RATE OF WEATHERING

APPARATUS FOR ACCELERATED DETERMINATION OF THE RATE OF WEATHERING OF PROTECTIVE COATINGS SUCH AS PAINTS. THE PAINT FILMS ARE SUBJECTED TO WATER SPRAY AND THE LIGHT OF AN ARC.

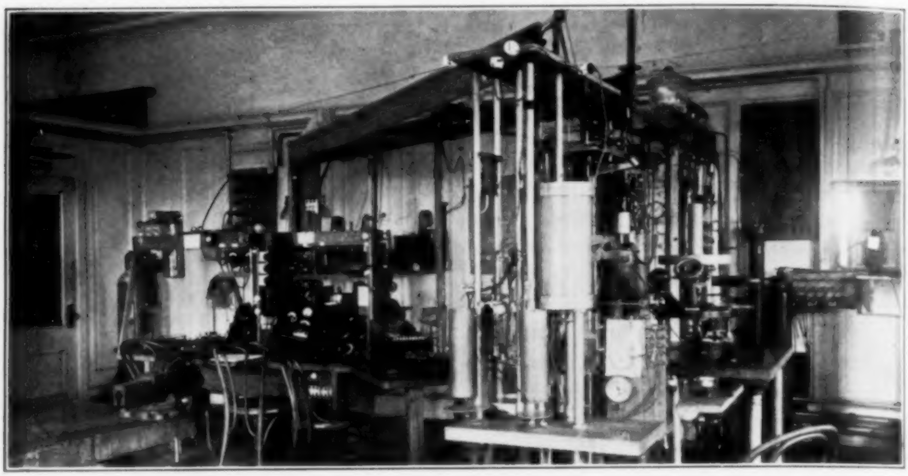


TESTING FUELS

FOR KNOCK CHARACTERISTICS IN NEW STANDARD CAR ENGINE.

there are but three laboratories in the United States equipped to make such tests as a routine matter. In about two years an undetermined property of cement became one of paramount interest for certain purposes.

Even though attention may have been called to it in previous articles in this series, the Bureau's work in the testing and certification of instruments used in industry should be mentioned. Practically all measurements in all industries are made with devices whose calibrations are based upon the fundamental standards maintained according to the Federal law at the Bureau. In many cases the actual calibration and certification has been carried out at the Bureau. In the majority of cases this has been done at the plant producing the device through comparison with standards received from the Bureau. Included in such apparatus are thermometers, pyrometers, scales, balances, weights, volumetric equipment, the many kinds of electrical measuring devices, proving rings for calibrating large capacity testing machines, cement of certain fineness for calibrating cement testing sieves,



MEASURING LATENT AND SPECIFIC HEATS OF WATER

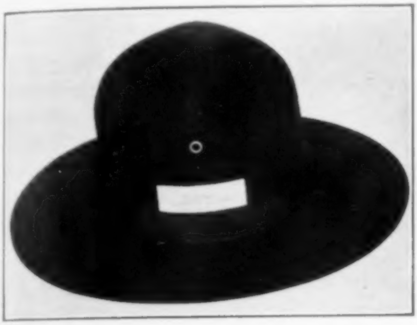
SOME OF THE APPARATUS USED IN A DIRECT MEASUREMENT OF THE LATENT AND SPECIFIC HEATS OF WATER AND THE SPECIFIC HEAT OF SUPERHEATED STEAM AT HIGH TEMPERATURES.

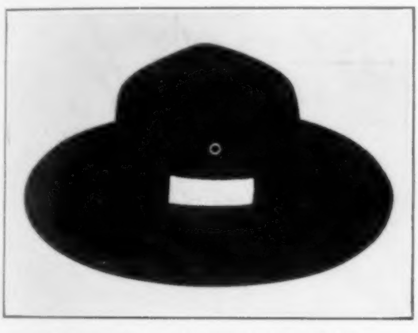
GLASS DISK FOR ASTRONOMICAL REFLECTOR

THE LARGEST ONE EVER CAST IN THE UNITED STATES IS SHOWN AT THE BUREAU OF STANDARDS IMMEDIATELY AFTER REMOVAL FROM THE MOLD IN WHICH IT WAS CAST. THE MOLD WAS MADE OF SOFT REFRACTORY INSULATING BRICKS, WHICH HAVE LEFT THEIR IMPRINT ON THE SIDE OF THE DISK. THE LENS STILL RESTS ON THE BRICK, WHICH CAN ALSO BE SEEN THROUGH IT. IN THE BACKGROUND IS THE FURNACE CONTAINING THE POT IN WHICH THE GLASS WAS MELTED, AND IMMEDIATELY IN FRONT OF IT THE PIT IN WHICH IT WAS ANNEALED.

pure metals and pure chemicals for use in calibrating pyrometers, calorimeters, standard solutions, etc. This kind of work is of absolute necessity in the production and sale of industrial materials.

The Bureau has at all times a very considerable percentage of its staff engaged in making tests of commodities, delivered to the various Federal Government purchasing agencies, to determine

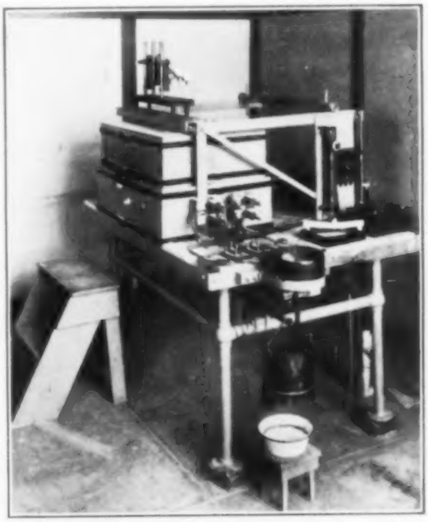




THE ALL AMERICAN HAT

THE REGULAR SERVICE HAT (TOP) IS TREATED WITH IMPORTED SHELLAC TO GIVE IT THE DESIRED STIFFNESS. THE LOWER ONE IS TREATED WITH A SYNTHETIC GUM MADE IN THE UNITED STATES FROM COAL, WATER AND LIMESTONE. BOTH HATS HAVE BEEN THROUGH FIVE MONTHS OF ACTIVE SERVICE AT FORT BENNING.

whether or not they meet the requirements of the specifications under which they were bought. While these tests are largely concerned with all the materials commonly used in construction, particu-

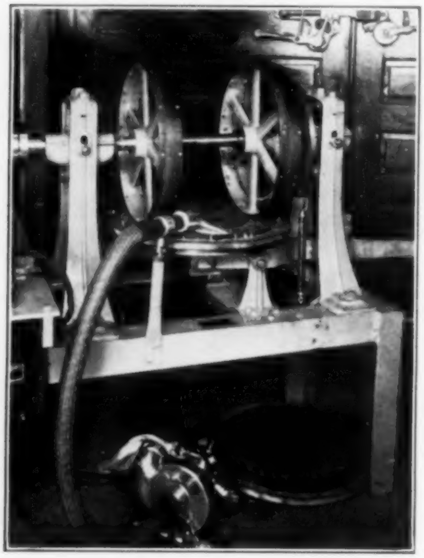


TESTING FIRE BRICK

SOME INDUSTRIAL MATERIALS ARE USED ONLY AT HIGH TEMPERATURES AND UNDER LOAD. THE APPARATUS ABOVE IS USED TO DETERMINE THE DEFLECTION UNDER ANY APPLIED LOAD OF FIRE BRICK AND OTHER REFRACTORIES AT TEMPERATURES UP TO 1250° C. THE WHITE BAR TOWARDS THE RIGHT EDGE OF THE TABLE SHOWS A SPECIMEN CUT FROM A FIRE BRICK AFTER A TEST.

THE GLARIMETER

DOES THE GLARE FROM THIS PAPER HURT YOUR EYES? THE APPARATUS SHOWN ABOVE IS USED TO MEASURE THIS PROPERTY OF PAPER.

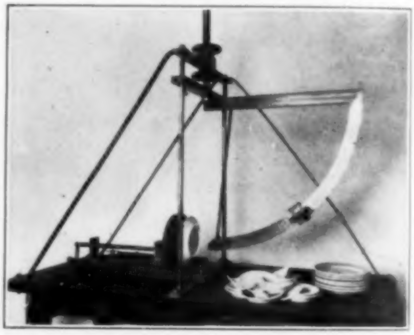


DETERMINING WEAR OF RUGS

THIS DEVICE HAS A LEATHER SHOE SURFACE FOR ABRADING THE RUG AND A VACUUM CLEANER FOR REMOVING THE ABRADED MATERIAL. A WORN SAMPLE IS SHOWN ON THE FLOOR BENEATH THE MACHINE.

larly of buildings, there is much time spent also in testing oils, gasoline, textiles, paper, leather, rubber, etc. This work is invariably supplemented with research interesting to producers, especially looking towards the proper use of commodities and the further development of the more desirable properties. The results are applied in the drawing up of specifications and their revision in connection with the Federal Specifications Board. In a later paper of this series attention will be directed towards showing how such specifications are brought to the notice of manufacturers to ascertain if they desire to be listed as suppliers of materials guaranteed by them to comply with the requirements of the federal specifications. This latter paper will present the work being done in aiding industries in eliminating excess sizes and varieties of various materials and establishing standards covering grades, quality, dimensional interchangeability or other acceptance criteria. The findings of the industries, including distributors and consumers as well as producers, are issued by the Bureau of Standards as "Simplified Practice Recommendations and Commercial Standards."

These efforts of the Bureau in connection with the preparation of specifications and the testing of government purchases of materials, so far as industrial materials are concerned, are most important ones. They serve particularly to bring the members of the staff working on the various commodities in direct contact with both producers and users. The staff thus obtains the view-point of both interested groups, realizes the limitations of the products as presented by the maker and the user, and serves to temper too severe service demands to



DEVICE FOR TESTING TABLEWARE

TABLEWARE, AS WE ALL KNOW, WILL BREAK AND CHIP AT THE EDGES. THE GOVERNMENT BUYS THE WARE FOR ITS BARRACKS, HOSPITALS, ETC., ON SPECIFICATIONS REQUIRING THAT IT SHALL NOT BREAK OR CHIP UNDER AN IMPACT OF LESS THAN A CERTAIN NUMBER OF FOOT POUNDS. THE ABOVE DEVICE IS USED FOR SUCH TESTING PURPOSES. NOTE THE PENDULUM WHICH CAN BE RELEASED AT CERTAIN POINTS ON THE STEEL ARC, GRADUATED IN FOOT POUNDS, TO DELIVER THE BLOW.

meet the production possibilities. At the same time it indicates how products may be modified so as to yield a commodity more nearly meeting service demands. The constant testing keeps information at hand showing when commodities have obtained qualities that will yield better or wider service through production refinements. This is passed on to interested users. The testing also at times may show the reverse, then just as properly the information is passed to the producers.

In many cases the specifications prepared through the Bureau's efforts have been developed only through intensive study. It is necessary at times to determine whether materials can be improved sufficiently to meet the increased service demands. This can be done by possibly making the product in question in one of the Bureau's mills. If the results are positive, the information is given to the interested industry which can apply them commercially. If negative, the user realizes his demands are excessive and he must either use what he has been accustomed to or turn to some other type of product.

Industrial materials, to be a live part of present-day commercial activities, must conform to certain standards of quality and standards of performance. These in turn must be based upon various standards of measurement and standard constants. Hence, it is quite evident why the Bureau, through its interest in fundamental standards and constants, also has through their application such a wide interest in the products of industry. It also indicates why the general public has come to rely so much upon the Bureau's work in this field.

BUILDINGS FOR THE PHYSICAL SCIENCES AT THE UNIVERSITY OF CHICAGO

The block-long line of scientific laboratories, devoted to discovering the secrets of the atom and the molecule. In these four structures, facing the main quadrangle at the University of Chicago, are the laboratories of many of the country's leading physicists and chemists. In the foreground is the new Bernard A. Eckhart Hall; second is Ryerson Physical Laboratory, seat of research for America's three winners of the Nobel Prize in Physics, Michelson, Millikan and Compton; third is Kent Chemical Laboratory; and facing the end of the walk, the new George Herbert Jones Laboratory.

THE PROGRESS OF SCIENCE

THE FOURTH CHICAGO MEETING OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE

GREAT has been the change in the American attitude toward science during the past hundred years. A century ago we had perhaps the least general interest in science of any of the larger countries. But now we have the most. Applied science in many different forms has now become more wide-spread with us than with any other people, and our population as a whole takes more interest in science than does the population of any other country.

This interest in science—especially in applied science—in the country as a whole was largely the result of the solution of the problems, engineering, agricultural, geological and others, arising from the development of our Middle West and West, in the region, therefore, of which Chicago is the central city.

So it was most appropriate that the association should join with the Century of Progress in laying before all classes of our people the scientific achievements of the past hundred years in this and other countries.

An outstanding feature of the Chicago meeting was the presence of about thirty guests from foreign countries, who joined with the members of the association in reviewing the recent development of science and in presenting the latest information on a broad range of scientific subjects.

It is a rare privilege to be able to learn directly of their work from our foreign colleagues, and to be able to meet personally those whose achievements are so well known throughout the scientific world.

On the first evening of the meeting the president and the board of trustees of the Century of Progress gave a reception in honor of the association and its associated and affiliated societies and foreign guests. This reception was held in the Hall of Science.

Perhaps the leading feature of the Chicago meeting was the large number of joint sessions and symposia and their unusual interest. Among these may be mentioned the symposia on the measurement of geologic time, on colloid chemistry related to biological problems, on the application of quantum mechanics in chemistry, on spectroscopy and astrophysics and on isotopes. Of more popular interest were the symposia on a century of progress in medicine, nationalism, social trends, government policies during a depression and education in a democracy.

Worthy of special mention was a general session under the auspices of Section B (Physics) and Section C (Chemistry) held on Wednesday evening at Northwestern University with Niels Bohr presiding, at which F. W. Aston outlined the story of isotopes and R. A. Millikan spoke on new light on nuclear physics. All three of these gentlemen have received the Nobel prize for outstanding work in physics or in chemistry.

The program for the Chicago meeting was unusual in that the four founder engineering societies, the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, the American Institute of Mining and Metallurgical Engineers and the American Society of Civil Engineers, met with the association. Meeting with these were the American Society for Testing Materials, the American Ceramic Society, the Institute of Radio Engineers, the Western Society of Engineers, the American Society of Refrigerating Engineers, the Society for the

Promotion of Engineering Education, the American Foundrymen's Association, the American Association of Engineers, the Society of Industrial Engineers, and the National Council of State Boards of Engineering Examiners. Under the auspices of the Society for Testing Materials came the eighth Edgar Marburg lecture, by Herbert John Gough, of the National Physical Laboratory, England, who spoke on crystalline structure in relation to failure of metals, especially by fatigue.

In connection with the engineering meetings there were a number of important conferences, among which may be mentioned a symposium on some fundamental problems of mutual interest to scientific economists and engineers, a conference on English, a conference on cooperative engineering education, symposia on alloys in steel castings, on cast iron, and on deoxidation and degasification of bronze foundry alloys, and a foundry housekeeping conference.

A most delightful and memorable event in connection with the meeting was the banquet given at the Hotel Stevens on Thursday, June 22, in honor of the foreign guests—Otto Appel (Agriculture), Berlin; F. W. Aston (Chemistry), Cambridge; Joseph Barcroft (Physiology), Cambridge; A. Mendelssohn Bartholdy (Political Science), Hamburg; Jakob Bjerknes (Meteorology), Bergen; Niels Bohr (Physics), Copenhagen; Filippo Bottazzi (Physiology), Naples; Ludwig Diels (Botany), Berlin; Jean Dufrénoy (Agriculture), France; Leopold Fejér (Mathematics), Budapest; Enrico Fermi (Physics), Rome; A. P. M. Fleming (Engineering), Manchester; R. Goldschmidt (Zoology), Berlin; Herbert J. Gough (Engineering), London; Sir Daniel Hall (Agriculture), London; A. V. Hill (Physiology and Medicine), London; C. U. A. Kappers (Anthropology and Physiology), Amsterdam; Wolfgang Koehler (Psychology), Berlin; August Krogh (Zoology), Copenhagen; Tullio Levi-Civita (Mathematics), Rome; Emilio Mira (Psychology), Barcelona; William Oualid (Political Economy), Paris; Henri Piéron (Psychology), Paris; J. J. Sederholm (Geology), Helsingfors; Charles E. Spearman (Psychology), London; T. Svedberg (Chemistry), Upsala; and R. J. Tillyard (Entomology and Paleontology), Can-

THE YERKES OBSERVATORY AT WILLIAMS BAY, WISCONSIN

THE McKINLOCK CAMPUS AT NORTHWESTERN UNIVERSITY

THE BUILDING SHOWN AT THE EXTREME LEFT IS PASSAVANT HOSPITAL; DIRECTLY ACROSS FROM IT IS THE MEDICAL SCHOOL BUILDING.

berra. The president of the association, Dr. John Jacob Abel, presided, and the toastmaster was Dr. R. A. Millikan. The speakers were Rufus C. Dawes, Hugo F. Simon, Filippo Bottazzi, Henri Piéron, Jakob Bjerknes, Wolfgang Koehler, Sir Daniel Hall and Edwin B. Wilson.

All the scientific establishments and institutions in Chicago deserve the grateful thanks of the members of the association for their numerous courtesies, which contributed so much toward making the meeting one long to be remembered.

Through the local committee many interesting excursions were arranged. Among these were trips to the famous Indiana Dunes, to "Wychwood," at Lake Geneva, Wisconsin, to the Yerkes Observatory, at Williams Bay, Wisconsin, and to the Stock Yards.

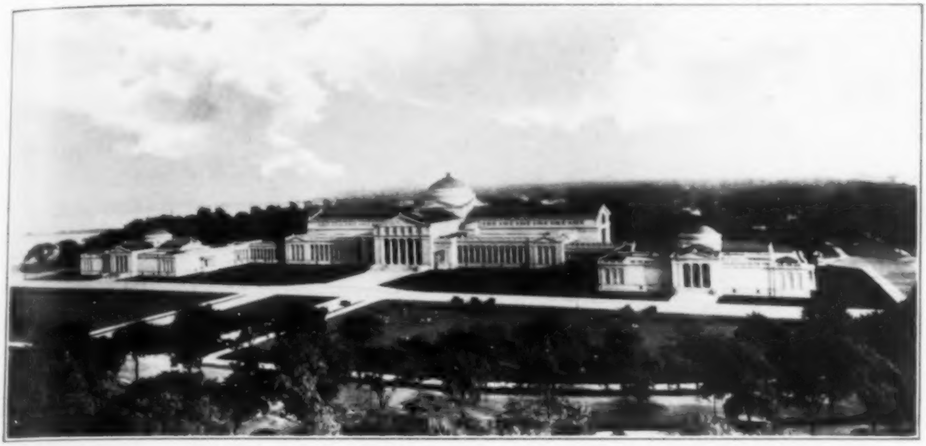
Elaborate provision was made for the entertainment of the ladies of the association, including visits to the Lakeside Press, Hull House, the Chicago Women's Club, Northwestern University, North Shore private gardens, Jackson Park and the University of Chicago. Mr. Leon Mantel, III, was so very kind as to tender the use of his yacht *The Buccaneer* for a cruise along the shores of Lake Michigan.

Chicago in itself is an unusually interesting city. It is the birthplace of the skyscraper, America's foremost contribution to architecture. As its buildings have grown higher, its streets have been widened—its growth has not been entirely haphazard. Burnham's admonition, "Make no little plans," has been followed literally. The park and boulevard systems, the forest preserves, the reversal of the Chicago River as an item toward the sanitation of the city, and the development of the Lakes-to-Gulf Waterway are all integral parts of the plan.

Chicago as a city well exemplifies the spirit of America; scientifically it is

DR. PHILIP FOX AND DR. C. U. A. KAPPERS

DR. KAPPERS, THE DISTINGUISHED ANTHROPOLOGIST FROM HOLLAND, STANDING WITH THE DIRECTOR OF THE ADLER PLANETARIUM IN CHICAGO.



THE MUSEUM OF SCIENCE AND INDUSTRY AT CHICAGO

preeminent as a center for that type of science that is peculiarly American. This American type of science, having as its aim utilitarian advance rather than philosophical refinement, was appropriately emphasized by the cooperation between the association and the Century of Progress.

The success of any meeting depends chiefly on the ability and energy of those who bear the brunt of making the local arrangements and looking after the multitudinous and aggravating details that inevitably arise. Fortunate it was for the association that the local arrangements were in the hands of such an able and energetic organizer as Colonel Philip Fox, who, ably assisted by Rufus C. Dawes, Roy K. Marshall, D. R. Curtiss, Andrew M. MacMahon, Walter Bartky, John R. Ball, Henry Crew and others, deserves the association's most grateful thanks.

Austin H. Clark

NOBEL PRIZE WINNERS IN PHYSICS AT THE AMERICAN ASSOCIATION MEETING

Professor F. W. Aston, University of Cambridge; Professor A. H. Compton, University of Chicago; Professor Niels Bohr, University of Copenhagen.

LAZARE NICHOLAS MARGUÉRITE CARNOT[1]

ONE hundred and ten years ago this month, on August 2, 1823, there died in exile in Magdeburg one of the most remarkable men of one of the most remarkable centuries in the history of France—Carnot, "l' Organizateur de la Victoire." Soldier, administrator, mathematician, physicist, new master in the construction of fortifications, the patriot who dared oppose the ambitions of Napoleon and who, when France called him, returned to the imperial standard in the fatal Hundred Days—this is the man to whom Bonaparte addressed these words after the defeat at Waterloo, "Carnot, je vous ai connu trop tard!"

Born at Nolay, Côte-d'Or, on May 13, 1753—one of a family of eighteen children, of which two developed into lieutenant generals, one became a councilor in the Cour de cassation, one a Procureur général of the Royal Court, another a directress of the hospice at Nolay—he came of good stock. In return he passed on the vigor of his clan;

[1] The medallion reproduced on this page is by David D'Angers and is in the Smith Collection in the Library of Columbia University.

for his eldest son, Nicholas Léonhard Sadi Carnot (1796–1832), was a physicist, author of the "Réflexions sur la puissance motrice du feu et sur les machines propres à développer cette puissance" (Paris, 1824), and was one of the first to comprehend the nature of heat as recognized by later scientists. The second son, Lazare Hippolyte (1801–1888), was one of the leaders in the movement for popular education. A grandson (son of Lazare Hippolyte), Marie François Sadi Carnot (1837–1894), became the fourth president of the Republic, fought for his country and, like his distinguished ancestor, now rests in the Panthéon, the Valhalla of France.

Educated in the Collège d' Autun and the École de Mézières, coming under the influence of D'Alembert and Bossut, he entered the army and here he made his early reputation both in the line of physics and in his work in the field of fortifications. The old system of defense, due to Vauban, was by him replaced by an improvement upon Montalembert's plan for the construction of forts, and his memoirs on the subject, following his "Éloge de Vauban" (1783), were looked upon as authorities for a full century after they appeared. His chief work on the theory was "De la défense de places fortes" (Paris, 1810). In his early days as a first lieutenant at Calais he also gave much attention to the subject of dirigible balloons, and his first communication to the Académie des Sciences was on "Le problème de la direction des aérostats." Although this was more than a century before dirigibles met with any notable success, he never lost confidence in the possibility of this mode of travel.

In 1783 he wrote his "Essai sur les machines en général," and twenty years later there appeared his "Principes fondamentaux de l' équilibre" (Paris, 1803), but he is chiefly known for his military achievements and his contributions to geometry. For training in the first of these fields the French Revolution supplied abundant opportunity. The members of the *Comité de salut public* (1793) were chosen by the convention, and Carnot was one of the most active, being charged with the organization of the armies, a position that challenged to the limit his scientific abilities. Copper was lacking for the guns, and he seized the bells of churches and convents; saltpeter was lacking, and he called chemistry to his aid; leather was needed for boots, and he demanded and secured new methods of tanning; guns must be had, and his knowledge of mechanics created them; the army was inefficient, and in a single year he organized fourteen armies; rapid communication amongst these armies was essential, and he helped perfect a new system of signals; reconnaissance of the enemy's positions was crude, and he used balloons.

In scientific circles, however, he will be known the best for his contributions to geometry. The "De la corrélation des figures de géométrie" (Paris, 1801) laid one of the corner-stones of the modern treatment of the subject, extended to three dimensions in his "Mémoire sur la Relation qui existe entre les distances respective de cinq points quelconques pris dans l' espace; suivi d' un Essai sur la Théorie des Transversales" (Paris, 1806). These were preceded by his "Réflexions sur la métaphysique du calcul infinitésimal" (Paris, 1797), in which he supported the Leibnitzian calculus and paved the way for Cauchy's notable memoir and for the elimination of the objections which Dean Berkeley (later Bishop of Cloyne) raised more than a half century earlier.

Mention should also be made of his assistance in the creation of two of the greatest schools of the world, the *École normale supérieure* and the *École polytechnique*, of the *Conservatoire des arts et métiers*—freedom's answer to the charge that the revolutionists were the children of ignorance and brutality.

David Eugene Smith

BALL LIGHTNING

ONE of the most difficult phenomena in nature to study is that known as ball lightning. It is so rare that comparatively few persons have ever seen it, and these observers have been so startled that they can not give a clear description of what they saw. Even a trained scientist would find extreme difficulty in making any worthwhile tests or measurements on a ball of blue fire as large as two fists which rolled along the floor for three or four seconds and then collapsed with a noise resembling a big firecracker, leaving behind nothing more tangible than the odor of ozone. Yet these are the salient points in the descriptions reported by C. F. Talman, of the U. S. Weather Bureau, in a recent popular article, also by E. W. Marchant and W. C. Reynolds in the 1930 volume of *Nature*.

During the thunderstorm seasons of 1929, 1930 and 1931, we have been engaged in a study of the electrical field changes caused by lightning discharges, with special reference to relation of the direction of branching of the flash to the sign of the field change. This involved photographing a large number of discharges at night, most of them at close range as the storm center approached or came directly overhead. The path of the storm centers was traced by means of a battery of microbarographs.[1]

On the evening of August 30, 1930, after a sultry day characterized by local thunderstorms in the surrounding territory to the south, a severe storm of the "line-squall" type developed in the west in the early evening. The wind had been scarcely perceptible from the southeast but changed to the southwest and increased to twenty or thirty miles per hour between 9:35 and 9:45. Rain, accompanied by high northwest winds, began at 9:53. The barograph record shown in Fig. 4 indicates an increase of .21 inches in pressure in the front of the storm, followed by an immediate rise of .06 inches when the active part of the storm, with its rapid convection currents, passed over the instrument. The time on this record is about twenty minutes slow, as this rise began at 9:35.

For making the photographs two cameras were placed in a fourth-story window above the trees and commanding a clear view of the western horizon. One of these is a 5 × 7 Graflex with a lens rated at f 4.5, the other an Eastman 1A Kodak with f 6.3 lens.

[1] J. C. Jensen, *Monthly Weather Rev.*, Vol. 58, p. 115, 1930; *Physical Rev.*, Vol. 40, p. 1013, 1932.

FIG. 1.

The cold air rushing ahead of the nimbus cloud was filled with a swirling mass of dust, but nevertheless brilliant flashes were seen descending in rapid succession from the cloud to the earth when the first films were exposed at 9:40 P. M. In the wake of one of these flashes there appeared a shapeless mass of lavender color which seemed to float slowly downwards. The writer was so occupied with the details of the photographic routine, which required the operation of shutters, the use of a stop-watch for timing the lightning-thunder interval, entering data in the note-book and telephoning to the assistant who had charge of the electrical recording apparatus in the laboratory, that there was little opportunity for close observation of this beautiful but unexpected display. The rose-colored mass seemed most brilliant near the ground and gave the impression of a gigantic pyrotechnic exhibition. Two or three of the globular structures seemed to roll along a pair of 2,300 volt power lines for 100 feet or more, then bounce down on the ground and disappear with a loud report.

FIG. 3.

FIG. 2.

The first five pictures, covering an interval of about three minutes, all show the fire-balls in one of their stages. Fig. 2 is an enlargement of the first Graflex picture at 9:40 P. M. The one caught at the same instant with the kodak resembles it closely, the lightning streamers in the rear being identical. Fig. 1 is a direct contact print from the second Graflex negative. It shows the principal descending ball in its most luminous and concentrated form. Although the shutter was open for only a few seconds, two brilliant lightning discharges appear in the background. The one in the center with streamers extending downward gave a field change which indicated that

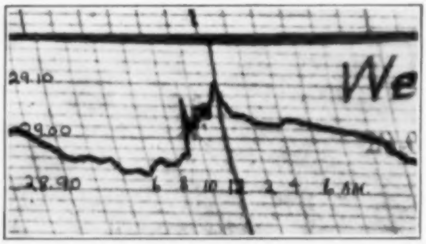


FIG. 4.

negative electricity had escaped from the cloud to earth. The kodak shutter was closed while Fig. 1 was being taken, but both cameras caught the final stage as shown in the enlargement of Fig. 3. The kodak lens was left open longer and shows less detail, together with blurring, due to motion of the illuminated balls.

As mentioned above, some of the fire-balls bounced off a power-line which was about 2,000 feet from the observer. Using the well-known optical formula relating the size of the object and the image to the object distance and focal length of the lens, the diameter of the first upper ball in Fig. 2 is shown to be 28 feet and that in Fig. 1, 42 feet. Their height above the horizon was 92 feet. It will be objected that these dimensions are so much larger than the conventional size that they must relate to different phenomena. However, Toepler[2] states the "masses of light" may vary in size from a hen's egg to 10 meters in diameter, and on another occasion during the course of our researches balls of similar magnitude were seen at a distance of two and one half miles but no photographic record was obtained. In this case also the balls collapsed with a sharp, loud report.

A tornado which occurred on the evening of July 9, 1932, near Rock Rapids, Iowa, gave evidence of a closely related type of luminous display, according to the report of Mr. George Raveling, U. S. Weather Bureau observer. From the sides of the boiling, dust-laden cloud a fiery stream poured out like water through a sieve, breaking into spheres of irregular shape as they descended. No streak lightning of the usual type was observed and no noise attended the fire-balls other than the usual roar of the storm.

While it is not the purpose of this article to propose a scientific explanation to account for the facts here related, meteorologists will find valuable material for study in the references given below.[3] Any of our readers who have witnessed these interesting phenomena are requested to send detailed reports to the author of this article.

J. C. JENSEN
NEBRASKA WESLEYAN UNIVERSITY

[2] Max Toepler, *Mitteil. d. Hermsdorf Schomburg Isolatoren*, Vol. 25, p. 18, 1926.

[3] Max Toepler, *Ann. d. Physik*, Vol. 4, sec. series, p. 623, 1900; Cawood and Patterson, *Nature*, Vol. 128, p. 150, 1931; W. C. Reynolds, *ibid.*, p. 584; also Vol. 126, p. 413, 1930; Mathias, *Comp. Rend.*, Vol. 194, p. 413, 1932; *ibid.*, p. 2257.